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MODERN VIEWS ON THE CONSTITUTION OF THE ATOM.*

BY

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INTRODUCTION.

THE view that matter is composed of discrete entities, called atoms, which are indivisible, is one of great antiquity. It was, however, merely a speculative opinion, not based on experimental evidence.

At the present day we can affirm that atoms have a real existence, using the word " real " in the ordinary sense; for instance, as a bullet or stone may be considered real. Moreover, it is possible to perform a number of experiments which indicate clearly that atoms are themselves composed of smaller entities, termed electrons, and it is not difficult to obtain some conception of the number and distribution and motion of these electrons within the atom. Furthermore, radio-active elements, such as radium or thorium, consist of atoms in a state of disintegration or devolution, and it has been possible to detect *single* electrons projected from radio-active matter, and also to ascertain that a radium atom may eject the large nucleus of the smaller helium atom. These

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remarkable expulsions from the inner citadels of certain atoms take place independently of their physical surroundings, such as extremes of pressure and temperature. It is noteworthy, however, that the manner in which these heavy atoms such as uranium and radium are built up from their smaller constituents, remains a profound mystery.

When the seventh Duke of Devonshire presented the Cavendish Laboratory to the University of Cambridge, the first Professor of Experimental Physics appointed was Clerk Maxwell, the Newton of electricity.[1] In his great treatise on "Electricity and Magnetism" he made a notable prophecy; namely, that the discharge of electricity through a rarefied gas is a phenomenon of great interest and importance, and, when better understood, "will probably throw great light on the nature of electricity as well as on the nature of gases and of the medium pervading space."

When Maxwell died he was succeeded by Lord Rayleigh, who found the units of electricity uncertain to some five per cent. This matter needed prompt attention, for electrical supply was then becoming a commercial undertaking. Rayleigh, in a few years, made it possible to determine with good accuracy the volt, the ampère, and the ohm. He retired, owing to his multitudinous duties and interests, and the University of Cambridge was somewhat startled to find the great Chair of Physics conferred on a "boy" of twenty-seven, the illustrious J. J. Thomson.

It would seem that he was born to prove the accuracy of the first half of Maxwell's prophecy, for he promptly investigated electrical discharges in gases, and the timely discoveries of the cathode rays and of Röntgen rays enabled him to make two great forward steps, namely, the theory of gaseous ionization, and a clear view of the nature of electrons.

When a current is passed from metal plates through a highly-exhausted tube a stream of particles is projected from one plate (the cathode). It was known that these were readily deflected by a magnet, but Sir Joseph Thomson succeeded in deflecting them also by an electrostatic field. He thus showed that the cathode particles, or corpuscles, are exceedingly light, with a mass about one-eighteen-hundredth part of the hydrogen atom. These corpuscles are now usually termed electrons, and are the fundamental units or atoms of negative electricity. It is scarcely

[1] Maxwell himself termed Ampère the Newton of electricity.

credible that this most primary conception can ever be dethroned from a foremost place in human knowledge.

Sir Joseph Thomson also gave us a theory of the manner in which a gas conducts electricity. If the molecules were all uncharged, then he believed that the gas would be a perfect insulator. The current of electricity in a gas is always carried by "ions," or charged molecules of gas which have gained, or lost, one or possibly more electrons. At low pressures or high temperatures the negative electricity may be conveyed by electrons instead of by negative ions; but positive electricity has never been found detached from atoms, or from the nucleus of atoms, so that the term positive electron has at present no concise meaning. Later we shall see Sir Ernest Rutherford's suggested interpretation of it.

It is necessary to write a few words about the radio-active substances, or radiants, as I find it convenient to call them.

There are about thirty-seven radiants known, and they are divided into three great families: (1) uranium-radium, (2) thorium, (3) actinium.

When any one of the atoms disintegrates it projects a fundamental part of the atom, either an alpha ray or a beta ray, with a high velocity into the surrounding space. That which remains of the old atom is a new atom of different physical and chemical properties to the parent atom from which the ejection took place.

The beta particle is an electron. The alpha particle is a helium atom stripped of two electrons. As the alpha particle slows down it picks up two electrons from some neighboring matter, and it is then an ordinary helium atom, and emits the same spectrum as helium.

Radiants may also emit gamma rays, which are closely analogous to Röntgen rays and are doubtless similar to light, consisting of ether undulations, but with wave-lengths several hundreds of times shorter than those of light.

Much theoretical deduction was confirmed when C. T. R. Wilson photographed illuminated ions, mist-ladened, marking the tracks of electrons, which had been hurled forth by a pencil of Röntgen rays (Fig. 1).

As Bragg surmised, the Röntgen rays did not ionize the gas directly. They ejected high-speed electrons, and these electrons, passing through the molecules, drove some low-velocity electrons

from the latter, thus giving rise to pairs of ions. The beautiful photographs of C. T. R. Wilson showed this very clearly. They bring us, moreover, abruptly face to face with one of the profound mysteries in physics.

Fig. 1.

The Röntgen rays are caused by the quick stoppage on a target of fast-moving electrons in the Röntgen tube. These rays, like light, must spread outwards with the flux of energy decreasing by the law of inverse squares. Yet when these diverging rays strike some one out of a vast number of molecules there is ejected

an electron with a speed almost equal to that of the primary cathode rays. The ejection may take place, moreover, many metres away from the tube. No explanation of this anomaly is forthcoming. The energy cannot come from the atom, for when the *intensity* of the rays is increased there is a corresponding increase in the *number* of ejected electrons. When the *frequency* of the waves of the Röntgen rays is increased there is an increase in the *kinetic energy* of the projected electrons. Indeed, we may write approximately that

$$\tfrac{1}{2}\, mv^2 = hn$$

where the left member is the kinetic energy of the electron, n is the frequency of the X-rays, and h is Planck's number equal to 6.6×10^{-27} erg second.

This interesting relation represents a fact, but explains nothing and itself demands as much explanation as the initial difficulty.

In conversation W. H. Bragg once gave to me a striking analogy. Let the moon represent the source of X-rays, and the moonlight, shining on the earth, represent the Röntgen rays falling on a body. Just as the Röntgen rays eject here and there a high-speed electron, so the moonlight would have to cause something about the size of a pea to leap out with great velocity, first one, say, from Siberia, then one from South Africa, next from New Guinea, and so forth. Violent and very local action produced by a uniform and homogeneous radiation!

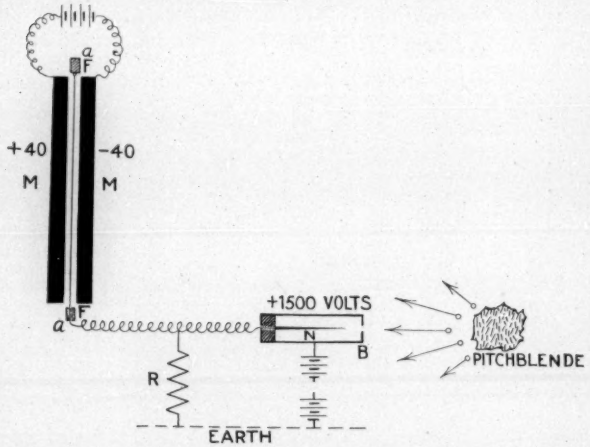
The Counting of the Alpha Particles.—Before C. T. R. Wilson had taken the photographs already described, Sir Ernest Rutherford had devised an apparatus which enabled him to detect the alpha particles entering, one by one, into a testing chamber in such a manner that their number could be counted. In this way he was able to deduce that the alpha particle had a charge twice as great, but opposite in sign, to the charge of an electron; that a gramme of the metal radium expelled 3.57×10^{10} alpha particles per second, and he found accurate values for other fundamental constants.

For the detection of the individual alpha particle this eminent physicist was, with a pretty humor, justly awarded the Nobel Prize for chemistry.

The Detection of the Individual Electron.—The alpha-ray

detector was altered and improved, and a few years later Geiger was able to report that he had succeeded in detecting *single* electrons entering a suitable orifice in his new testing chamber. As I had, owing to the kind help of the secretary, Dr. Owens, the pleasure of performing experiments with this type of apparatus at The Franklin Institute, it may be well to give a fairly full description of it.

FIG. 2.



B is a hollow brass cylinder (4 x 1 cm.) with a small hole in the end (where the electron enters). Voltage + 1500. *N* is a fine, sharp, clean needle with its point about 8 mm. from the hole. *R* is a high resistance, about 100 megohms, of xylol and alcohol in a glass U tube. *FF* is a fine, silvered, quartz fibre between two metal plates 8 mm. apart, 15 cm. long, charged to low opposite voltages.

When an electron, say a beta particle from a radiant, enters the small hole in the testing vessel *B*, it approaches a point *N* which is almost sparking to the high-potential chamber (Fig. 2). The ions produced by the particle, particularly the negative ions, are urged forward with a very high velocity by the intense electric field, and these ions produce more ions by collision. It is as though a temporary minute spark passed, so that the needle leaps up from zero to 36 or 40 volts. As the needle is connected to the quartz fibre *FF* this latter is at once charged, and, being between charged plates, is deflected. A stable state is swiftly re-

established, owing to the high resistance R, and the trap is reset to show the next electron. The movements of the quartz fibre are seen when projected on a white screen. With this apparatus many beautiful experiments can be shown, such as the range of the alpha particles from polonium; individual alpha particles passing through a pinhole in paper; the reflection or scattering of rays from lead or from aluminum, in which case the lead is the more effective; the long-distance effect of the gamma rays and their highly-penetrating nature. But the most excellent and impressive sight is that of a piece of pitchblende, just as it came from the mine in Bohemia, continually expelling alpha and beta particles into the surrounding air. Remember also that it is capable of continuing to do so for a period exceeding one thousand million years.

On the Nucleus of Atoms.—Sir Joseph Thomson had suggested an atomic structure having a number of electrons revolving in concentric circles within a vague entity consisting of positive electricity. Sir Ernest Rutherford, working with Geiger, found that when alpha particles bombarded thin gold leaf the great majority of the particles passed through, but about one in every eight thousand returned on the side of entry. He came to the conclusion that the returning alpha particle had encountered a highly-charged nucleus. Working out this idea on the basis of Newtonian mechanics, he concluded that the nucleus was small in its effective dimensions, but that it had a charge equal to about one-half of the atomic weight of the atom. This idea was amply verified by a long series of experiments, and it fitted well with results obtained by Barkla, who, stimulating matter with Röntgen rays, obtained evidence that an atom contained electrons to a number about half that of the atomic weight.

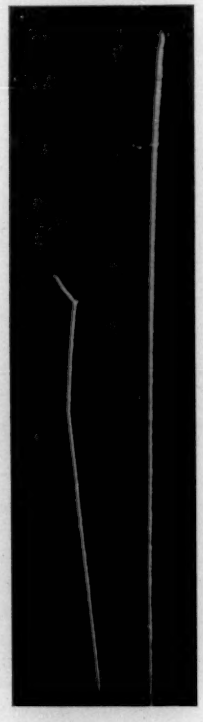
Putting these results together, we obtain something resembling a miniature solar system, with the minute central body consisting of a large positive charge, and in concentric surrounding rings are electrons revolving like planets,[2] but perhaps with several in each ring, and so adjusted that their total charge, which is negative, balances the positive charge on the nucleus.

The Alpha Particle and Hydrogen Nucleus.—In one of Wil-

[2] There is, however, no direct experimental evidence that the electrons revolve. They may vibrate about stable positions.

son's photographs of the track of an alpha particle (Fig. 3) there appears, near the end of the path, a small projecting spur, which he explained as due to an atom of an air molecule, struck by an alpha particle, receiving sufficient velocity to ionize the air for a

Fig. 3.



short distance. It immediately occurred to Rutherford that if an alpha particle passed through hydrogen, then the light hydrogen atom, or rather its nucleus, would be projected, not merely to a greater distance than the nucleus of the oxygen or nitrogen

atom, but to almost four times the distance of the alpha particle itself. This forecast was verified by Marsden, using a zinc sulphide screen, when the scintillations due to the hydrogen nuclei were seen at a range nearly quadruple that of the alpha particles. This important verification has placed the theory of the nucleus on a foundation which excludes doubt as to its reality.

The Beta and Gamma Rays.—Another photograph was obtained by Wilson showing the long range of the electron expelled by incident gamma rays. In air at atmospheric pressure this secondary beta particle will traverse more than a metre. As will be seen later, the gamma rays are electromagnetic disturbances having a minute wave-length, even compared with light waves, and a correspondingly high frequency. The kinetic energy is, as with Röntgen rays propelling electrons, again approximately equal to h times the frequency, when h is Planck's constant. The mechanism by which these phenomena occur is unknown, whether we consider electrons projected by ultraviolet light, Röntgen rays, or gamma rays.

Planck's Constant.—When in a reflecting enclosure there is a heated body and, necessarily, ether, the former has a limited number of degrees of freedom, and the latter an unlimited number. It may, therefore, be expected that, as theory appears to indicate, the energy of the body would decrease and that of the ether increase, particularly towards vibrations of the shorter wave-lengths. Experiment proves that this does not occur, and that the distribution of energy is utterly different from that which Newtonian mechanics demands. Planck found himself able to explain this distribution only on the supposition that energy could leave the oscillators in the body by exact *quanta*, the magnitude of which was in each case proportional to the frequency of the oscillator, or equal to hn. Shortly before his death Poincaré thoroughly investigated this hypothesis and concluded that an explanation on the basis of Planck's hypothesis was inevitable, and that no other view was in accordance with observed radiation phenomena. An able summary of the whole subject has been given by Jeans in a report published by the Physical Society of London.[3] We have, therefore, a unique situation in physics. The quantity h has been introduced and its magnitude

[3] "Report on Radiation and the Quantum Theory," by J. H. Jeans, *The Electrician* Printing Company, Fleet Street, London.

determined without our having any approximate idea of what h represents. To the student of radio-activity it is the ratio of the number of units of the kinetic energy of the projected electron, divided by the frequency of the incident electromagnetic disturbance, or possibly by some exact multiple of that frequency.

Röntgen Rays and Crystal Reflection.—It was foreseen by Laue, at a time when the potentialities of Röntgen rays appeared almost exhausted, that these rays would be scattered in a definite direction from any set of orderly parallel planes in which the atoms of a crystal are arranged. An analogy may be useful. If troops with fixed bayonets are not drawn up in rank the sunlight reflected from the bayonets will give to a spectator a glint here and there. In well-dressed ranks, however, a spectator will in some positions see no reflections, but in other positions, when the angles of reflection and incidence are equal, he will obtain a powerful flash from all the bayonets in all the ranks.

Professor W. H. Bragg and his son have developed this method and obtained information as to the distribution of atoms in various crystals, the distance between the atoms, and the wave-lengths of the Röntgen rays. He has himself summarized this work in an article published recently in *Science* (December 4, 1914).

Crystal Reflection of Gamma Rays.—The gamma rays have been reflected from the regular layers of atoms in a crystal in a manner quite similar to that employed with Röntgen rays, a radiant taking the place of the X-ray tube. In this way Rutherford has found that the wave-lengths of the most penetrating gamma rays, glancing from the crystal face at 42′, is about 0.7×10^{-9} cm. This is the smallest wave-length known, but the phenomenon may as justly be attributed to an electromagnetic disturbance in the ether as a radiotelegraph wave with a length of several kilometres.

It is interesting to note, in some papers of Rutherford's, how he appears to use language and ideas which are at present totally irreconcilable. I am not venturing to criticise this, for the statements do indeed represent the facts. At one time Rutherford is speaking of "a gamma ray," thus suggesting *linear* propagation of energy, and at another time he is discussing the wave-length of a gamma ray with a meaning applicable to ordinary light radiation and therefore involving an expanding wave front. We are re-

minded of Newton's troubles in explaining diffraction by a corpuscular theory, and concluding that light has an "eel-like" motion.

Atomic Number.—Since the positive charge on the nucleus of an atom is about half the atomic weight, and since that charge is necessarily a whole number when expressed as a multiple of the magnitude of the charge of an electron, it has been suggested by van den Broek that there is a fundamental and important number connected with every element, known as the atomic number. This number is possibly the place of the element in the periodic table (H 1, He 2, Li 3, Be 4, Bo 5, C 6, etc.). This theory has had strong confirmation from a series of experiments by Moseley. He exposed most of the elements to the bombardment of electrons in a vacuum tube, these elements forming, in turn, the anticathodes of a Röntgen tube. The natural or characteristic radiations of the elements were reflected from a crystal surface, and the frequencies of the vibrations were thus determined. After a correction for the outer electrons, it was found that in every case the frequency was proportional to the square of an integer which was identified with the atomic number. According to Sir Joseph Thomson, when an atom has, suppose, three rings of revolving electrons, the outer ring is that influenced by ionization and is investigated by spectrum analysis, the inner ring is connected with the penetrating, or hard, or K series of characteristic Röntgen radiations, and the middle ring with the less penetrating, or soft, or L series. To the nucleus we must look for the main effects of mass and inertia, and gravitational attraction, and, when they exist, for the radio-active transformations and expulsions.

Bohr's Theories.—It has been pointed out that when a single electron revolves round a unit charge nucleus, as in the case of hydrogen, that by electromagnetic theory there should be a continued stream of energy radiated away into space, necessarily demanding that the revolving electron would lose speed and fall into the nucleus. To overcome this and similar difficulties, Bohr has suggested a theory of stable states, non-radiating, with the angular momentum an exact multiple of $h/2\pi$, where h is Planck's constant. When the multiple is, for reasons unknown, diminished by unity, the electron abruptly changes from the old stable state to the next stable position, and in doing so radiates away an exact quantum such as Planck first conceived. It must be ad-

mitted that these ideas appear at first highly imaginative, and they might well be ignored but for the remarkable degree of success which they have already achieved. Notably he foretold the existence of certain lines in the ultra-violet spectrum of hydrogen, and these were subsequently discovered by Lyman. He identified lines found by Paschen in the infra-red, and also obtained an excellent numerical verification between his theory and the value of the constant of Rydberg which links up the spectral series of various elements. Perhaps the most interesting suggestion is that lines seen in the spectrum of certain stars may be assigned to hydrogen in a state of extreme tenuity, so that the electron revolves in a greatly-enlarged orbit about the nucleus, a state which it is impossible to imitate in the small vessels of our laboratories.

Valency Law of Radiants.—A band of chemists who have made a careful study of the properties of the radio-elements have succeeded in the discovery of an interesting law which removes the difficulty of finding places in the periodic table for all the radiants, about thirty-seven in number. A full account of this work is given by Soddy in "The Chemistry of the Radio-elements" (Longmans, Green & Co., 1914).

Briefly, it has been found that when a radiant expels an alpha particle, thus reducing the charge on the nucleus by two electronic units, there is a corresponding change of valency, say from tetravalent to divalent, so that the new product is two columns to the left in the periodic table, while the decrease of atomic weight is four. When a beta particle is expelled there is no effective change of atomic weight, but the nucleus charge or atomic number has increased by one, since the loss of a negative is equivalent to the gain of a positive electronic unit charge. The subsequent product is now found one column to the right in the table, relative to the parent element. Two elements with different atomic weight, but with the same nucleus charge, may find themselves in the same place in the periodic table, and are known as isotopes. Such elements have chemical and physical properties so similar that they are at present deemed inseparables or non-separables. As an example, it is possible to obtain radium D as it forms from the disintegration of radium C. If this radium D is mixed with lead, separation becomes impossible, because their chemical

properties are identical. This theory has already achieved a notable success. In the early days of radioactivity Sir William Crookes obtained uranium X by chemical separation from uranium, and it was shown that it was a linear descendant. The uranium was found to eject two sets of alpha particles of different ranges, so that it was presumably two radiants and not one. The law above described suggested both the presence of an undiscovered radiant and also its chemical properties. This substance, uranium X_2, or brevium, for it is short-lived, was quickly discovered.

The conclusion arrived at is set forth in the following typical scheme, where uranium 1 and uranium 2 are inseparables or isotopes, with atomic weights differing by 4, but with atomic numbers and valencies identical.

IV.	V.	VI.	At. wts.
$Ur\ X_1 \rightarrow$ β, 90	$Ur\ X_2 \rightarrow$ β, 91	Ur 2 α, 92	234.5
		Ur 1 α, 92	238.5

The Positive Electron.—In the early days of the electron theory it was not unnaturally supposed that the positive electron was similar in general character to the negative electron, the two, of course, neutralizing one another. The diligent search of many eminent physicists has failed to obtain evidence of any such entity, and in no case has a positive electronic charge been observed except accompanied with a mass of atomic dimensions. Sir Joseph Thomson has found that the hydrogen atom, alone of the elementary atoms, never loses more than one electron. It has been suggested by Sir Ernest Rutherford that the long-sought positive electron may, in fact, be the nucleus of the hydrogen atom, and, in that case, that its mass would be 1800 times as great as the mass of the negative electron. If this mass is electromagnetic in character, it must vary inversely as the radius, so that the positive electron would have a sphere of action extremely minute,

even compared with the negative electron. The radii of the three spheres would then be of the following orders:

Atom, 10^{-8} cm.
Electron, 10^{-13} cm.
Positive electron, 10^{-16} cm.

It is clear that the investigation of the inner constitution of the electrons will offer formidable difficulties to future generations of physicists.

CONCLUSION.

There are generally not a few men of small intellect or foresight who ask, "What is the good of these philosophical discoveries?" Such is not the attitude of those who are engaged in the practical work of applying scientific discoveries to the benefit of mankind. But, apart from inventions, so often misdirected to the destruction rather than the elevation of the human race, it is well to urge continually the high aim of the search for truth for its own sake, wheresoever it may lead us. It may be noted that the discoveries set forth in this brief summary have been achieved by savants in the western half of Europe, and it may be asked if the education in the New World is at the present time sufficiently thorough, imaginative, and philosophical. In any case, the future improvement of mankind is likely to arise from education in the sense of development of knowledge, character, and principles, rather than from the acquisition of wealth, or by the multiplication of material resources.

Magnetization in Rapidly-oscillating Fields. H. Rohmann. (*Ann. d. Physik.*, xliv, 6, 817.)—A magnetized bar is more or less demagnetized when placed in an oscillating magnetic field of which the amplitude continuously decreases. On the other hand, an unmagnetized bar may be magnetized by means of the discharge of a battery of condensers. The magnetism produced depends partly on the amplitude of the alternating magnetic field and partly on the manner in which the field diminishes to zero. Further, the magnetizing action of a damped vibration changes qualitatively even when its course is changed by a definite but relatively small amount. Experiments are described showing the effect of the superposition of two damped sine oscillations which give rise to more complicated vibrations.

THE MODERN SUBMARINE IN NAVAL WARFARE.*

BY

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WHEN I accepted the Institute's invitation to address you, war had not been declared, but since its declaration the history of the submarine in warfare has been in the making, and so much has happened and was likely to happen, bearing on my subject, that I postponed preparing any paper until the last minute, and so, I fear, should apologize for it.

As an actual designer and builder of submarines I am fairly new at the game, though I have to draw on, the accumulated experience and advices of my colleague, Mr. Simon Lake, one of the pioneers in the practicable submarine field.

Most of my early experience in the field of design and construction was with surface warships, with which I may claim reasonable familiarity, having, during an eight years' tour of duty as assistant to the chief constructor of the navy, supervised the design of every dreadnought now in commission in our service and half of those now building, together with numerous other surface craft of all types.

It is, therefore, on my knowledge of the vulnerability of the dreadnought type to submarine attack as much as on my knowledge of submarines that I must base my right to talk to you.

In the beginning permit me to say that I am not one of those who believe the submarine a cure for all naval ills, or that it will supplant surface warships.

I am, however, and have always been, a strong advocate of the submarine as one of the most powerful naval weapons of defence, and as possessing offensive qualities which, in the fulness of time and with the development of engineering science, cannot be minimized.

The wording of my subject might imply that I expected to pose as a prophet, but I should prefer, if I may, to show you

* Presented at the meeting of the Mechanical and Engineering Section held Thursday, December 10, 1914.

certain facts and in most instances to allow you to make your own prophecy.

Admiral Sir Percy Scott, of the Royal Navy, in his now famous letter to the *London Times* of June 5, this year, took the strongest possible stand for the submarines and, incidentally, against the battleships, concluding his letter with the statement: "In my opinion, as the motor vehicle has driven the horse from the road, so has the submarine driven the battleship from the sea."

Coming as it did from one who had contributed so much to the development of the battleship offensive power, this letter made an enormous impression, though I cannot but believe that Admiral Scott stated the case somewhat more strongly than was justified or than he himself really believed.

What may very well be the case is that the effect of the submarine will be to reduce the rapid growth in size and expense of the dreadnought type, now reaching to almost unbearable amounts.

The menace of the submarine arises, first from her invisibility, and, second, from the fact of the difficulty of providing against the damage which will result from a blow from the weapon she carries.

Sir John Biles, LL.D., in a recent paper before the British Institute of Naval Architects, says:

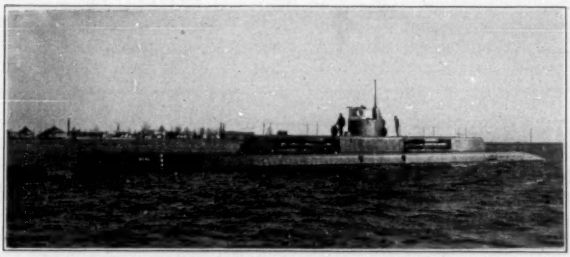
"There can be only two forms of defence: first, the destruction of the submarine by other vessels, submarines or others; second, the protection of the bottom of the surface ships from the effect of under-water attack. The first, the destruction of the submarine, is obviously not the work of a battleship or large cruiser, but must be left to some vessel of the same order of size as the submarine. This destruction must be sought on the surface when the submarine is not submerged, for it seems improbable that a submarine will be able to chase another effectively under the water. In any case, the submarine will be dangerous to the large surface ships until it is destroyed, and, as the means of destruction are not yet certainly at hand, the question of effectively protecting the battleship against under-water attack seems to be deserving of consideration, unless some one is ready with a real reply to the submarine."

A great deal of attention has been given by naval architects to providing, in the dreadnoughts, protection against the auto-

mobile torpedo, with astonishingly small success up to the present time.

I personally struggled with this question for a good many years, and I believe, without conceit, that the United States has to-day as good a solution as has yet been obtained, but even that is by no means perfect.

For a ship at anchor a reasonable protection against the possibility of damage from the automobile torpedo may be obtained by the use of torpedo nets, although the development of the net cutter, attached to the torpedo's nose, has made even this uncertain. It is almost impossible to use a torpedo net on a ship under way. In the first place, it enormously decreases the speed and handiness and enormously increases the fuel consumption of the



Submarine (*Seal*) G 1, U. S. Navy (Lake type).

vessel wearing the net, and, in the second place, the mere fact that the vessel is under way causes the bottom of the net to rise to the surface and thereby largely does away with the advantage of the net.

This being the case, the only remaining possibility is to include within the structure of the vessel itself provision against damage by attack from a torpedo. Unfortunately, it is much easier to increase the power of the torpedo than it is to increase the defensive protection built into the hull of the dreadnought, with the result that, if any given class of surface ship has protection against the then existing torpedo, it is fairly easy to vitiate the value of this protection by increasing the power of the torpedo.

Briefly, the provisions which may be embodied in the design

of a ship against the damage of the torpedo comprise under-water armor, additional compartmenting, and compressed-air installation for localizing the inflow of water. The under-water armor, on the face of it, looks like a good solution of the problem, but, as a matter of fact, it is of very little use to put under-water armor on the external hull of the ship. A torpedo explosion has a crushing effect, which results in tearing the riveted joints. The rivets seem to be attacked in detail, and an increase in the amount of metal applied externally does not do away with the necessity for riveted joints, and, if under-water armor were put on the ship in the same manner as the above-water armor, there would be *no* connection at the joints, since the armor above water is simply plastered up against a backing plate.

Careful and minute compartmenting, of course, covers a large number of possibilities, but provides only against the damage done by the torpedo in localizing the effect of the damage.

The compressed-air installation is a means of preventing water entering the body of the ship in too large volumes as the result of any damage done by a torpedo. It has to be specially applied, utilizing what is called the "backing up" method, using pressure in the adjacent compartments of varying degrees so as not to damage the ship's structure by the air-pressure.

The best solution of the problem is a combination of the three methods referred to above:

Proper compartmenting—and by this I mean something different from the time-honored system in use in the older days—under-water armor not located on the external hull of the ship and so designed as to give a maximum strength to the structure of the ship, and a graduated compressed-air installation for checking the water after it gets into certain compartments which cannot be prevented.

There are several essential features in designing a surface ship and in providing these anti-torpedo protective features which must be looked out for. The principal among these is the effect on the longitudinal or transverse trim of the vessel, from water getting into one or more compartments. The question of longitudinal trim is ordinarily not as important as transverse, and provision may be made, and has been made, for balancing transverse trim or list by admitting a similar amount of water on the opposite side to that damaged. This course results in a greater

sinkage and consequent reduction in speed and safety of the vessel, but, when a balancing system is properly arranged in combination with the defensive means mentioned above, it should probably result in the ultimate salvage of the ship, although her value as a fighting unit after the damage from the torpedo would probably be little or nothing for the time being.

The British cruisers *Aboukir, Cressy,* and *Hogue,* which were sunk by the German submarine *U*-9, were, of course, not ships of the most modern type. They, however, represent a very excellent type of ship of some fifteen years ago, and the fact that each of them sank as the result of a blow from a single torpedo indicates plainly enough the fact that a ship of very little age soon becomes practically out of it when subject to the danger of submarine attack.

The more recent sinking of the dreadnought *Audacious* brings this thought more forcefully to our minds.

The submarine, as you know, is not at all a new idea; in fact, some very excellent conceptions of submarines are quite old. Any one desiring to investigate this fact has but to read the interesting and complete work on "Submarine Navigation," by Allen W. Burgoyne, who rehearses the various types of submarines projected or undertaken by all manner of people since before the beginning of the Christian era.

The list of inventors includes men of all nationalities and from all walks of life, doctors, clergymen, lawyers, military men, and mechanics.

Some of the projects were absurd, many were never undertaken, but others had excellent ideas, and were perfectly practicable, except in one essential particular: a proper prime mover for propelling and auxiliary power.

The early boats were, of course, propelled by hand, no other power being then known, and it takes little imagination to understand how laborious this was and how little speed or control could be expected from a craft so propelled.

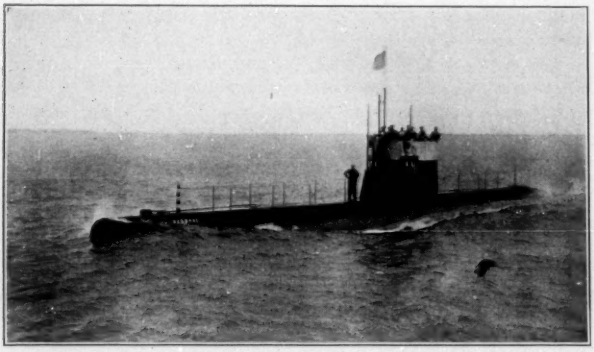
It was not until steam had been used as a motive power in surface ships for many years that a really operable submarine was produced, and not until the development of the internal-combustion engine and the storage battery that the submarine became the well-developed instrument that we know to-day.

Strangely enough, there has been of late a return from the

internal-combustion engine to steam in certain instances for surface propulsion, but so far the storage battery holds undisputed sway as a source of power for under-water work.

The submarine at present must carry two entirely distinct and separate sources of power, one for surface work and one for submerged work, and the storage battery per unit of power is very heavy.

I have kept before me for years a sign that reads: "The man who says a thing is impossible is apt to be interrupted by somebody doing it." So I shall not say that any means of under-water propulsion other than storage batteries is impracti-



Submarine *Narwhal*, U. S. Navy (Holland type).

cable, but at the present time no other practicable means is apparent, and it is this very fact that is the greatest restriction confronting the submarine designers and builders.

The essential features of any submarine from a military point of view are surface speed, surface radius, submerged speed, submerged radius, and armament.

Surface Propulsion.

The early successful submarines had gasoline engines. These were later superseded by heavy oil engines of the Diesel cycle-first, four-cycle engines, and, more recently, two-cycle engines, of which several types have been used. None of these can be

said to be perfect yet, but great improvements have been made and are still making.

The high pressures and temperatures that occur in the Diesel engine result in stresses that are serious, and the high speed and comparatively light construction that must be obtained in submarine engines give a chance for trouble that might not exist in a slow-going installation.

Mr. J. T. Milton, in a paper read before the British Institution of Naval Architects in April, 1914, says:

"Diesel engines are broadly divided into two classes, viz., the two-stroke and the four-stroke cycle, respectively. In both types a cylinder full of air at atmospheric pressure is compressed by the piston till at the top centre its pressure becomes about 500 pounds per square inch. The compression raises its temperature to about 1000° F. At this instant a small quantity of oil fuel is blown into the very hot high-pressure air by means of a blast of air at a still higher pressure. The arrangement of the fuel valve and its gear is such that the oil is broken into a fine spray, and its admission lasts only for the short time which it takes for the piston to perform about one-tenth of its downward stroke. During this short time much of the oil becomes burned in the hot air. The heat generated by the combustion raises the temperature considerably, and, consequently, must increase either or both the pressure and the volume occupied. What is aimed at is that the combustion should proceed at the critical rate which would permit the increase of volume occupied due to the motion of the piston and the increase of temperature to be so balanced that the pressure will remain constant until the whole of the oil has been burned. After this the expansion of the hot gas will still further push the piston down, and the pressure will rapidly decrease. The temperature will also rapidly fall, mainly through the conversion of some of the heat into work, but partly also by some of it being conveyed into the cylinder surfaces, these being kept comparatively cool by water circulation. The maximum temperatures actually attained in the cylinders are very high, approximating, in some cases, to nearly 3000° F. It is these excessively high temperatures which occasion some of the special difficulties of Diesel engines. It is necessary to keep the rubbing surfaces of the metal, which are exposed to the hot gases, sufficiently cool to

permit of their retaining their lubrication, and it is also necessary to prevent all the metal with which the heat comes into contact from becoming so overheated as to damage its strain-resisting properties.

"The foregoing remarks apply to all types of Diesel engines. In the case of the two-stroke cycle engine, just before the completion of the expansion stroke, the piston uncovers some ports in the lower part of the cylinder walls leading into an exhaust passage, and a considerable portion of the hot gas escapes, the pressure falling to about that of the atmosphere; then in some designs some valves in the cylinder cover are opened, and fresh air supplied by the scavenging pump at a pressure of about 4 pounds per square inch blows out the remainder of the burnt gas, leaving the cylinder full of fresh air ready to be compressed by the return stroke of the piston. In some designs the exhaust ports are placed on one side only of the lower end of the cylinder, and on the other side similar ports, also opened by the travel of the piston, but at a somewhat later instant, admit the scavenging air. In these cases the tops of the pistons are curved to direct the entering air upwards, and it is claimed that the scavenge air travels right to the top of the cylinder and entirely displaces the burnt air. In these latter designs the scavenge valves and the gear for working them are dispensed with, and, consequently, the engines are to some extent simplified."

Storage Battery Plant.

The safety and success of the attack of a submarine depend to a great extent on her ability to approach the enemy while submerged and to remain submerged for a long time. In a high-sea engagement the enemy's fleet may naturally be assumed to be under way at some speed, so that the development of the sea-going type, to which some reference will be made later, will logically include some increased submerged speed and considerably increased submerged radius for manœuvring in the vicinity of the enemy for a long period.

Increased submerged speed and increased radius of action submerged will make the batteries proportionately larger than are at present used.

In the case of the sea-going type of submarine the design of the storage battery requires study in order to get the battery best

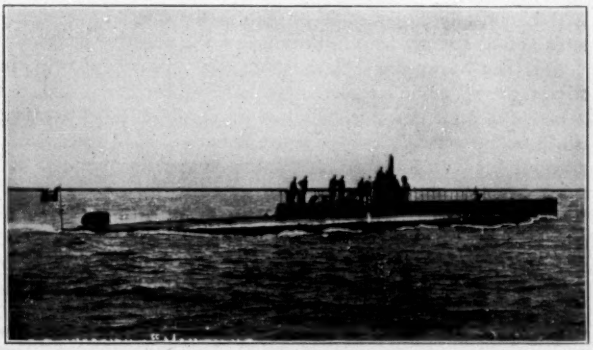
adapted to obtain the maximum speed submerged and the greatest radius of action along with a reasonable length of life.

Storage Batteries Used on or Proposed for Submarine Boats.

There are two general types of storage batteries in more or less general use at the present time, namely:

Class A—The lead type, using as electrolyte sulphuric acid of a density of about 1.230.

Class B—The iron-nickel type, using as electrolyte caustic soda, known as the Edison battery.



Submarine *Nautilus*, Italian Navy (Bernardi type).

Of these, so far as I know, the lead battery is the only one that has yet been used in submarines, newspaper stories to the contrary notwithstanding.

The lead type (Class A) uses peroxide of lead as active material on the positive plates, and spongy lead as active material on the negative plates, immersed in an electrolyte of H_2SO_4.

This general type embraces three distinct methods of manufacture of the individual plates, known as the "Plante" or electrochemically formed plates, the "Pasted" type of plate, and the "Ironclad" plate, which is a particular construction of a "Pasted" type of plate.

(*a*) The "Plante" (sometimes called "High surface") plate is made of a fine grid which is either cast, grooved, or spun in such a manner as to produce a very large superficial area

available for electrochemical action. The grid is then subjected to an electrochemical process whereby the lead on the surface is reduced to peroxide of lead for the positive plates and spongy lead for the negative plates. On submarines the "Plante" positives are used in combination with "Pasted" negatives wherever the "Plante" plate is used.

(*b*) The "Pasted" plates have grids cast of lead with a small percentage of antimony, and usually consist of a frame supporting a network of meshes into which the "Paste" from which the active material is formed is pressed, and then reduced electrochemically to peroxide of lead in the case of the positive plates and to spongy lead in the case of the negative plates.

(*c*) The "Ironclad" plate has the frame for supporting the active material made of perforated hard-rubber compound, consisting of a series of finely-slotted, hard-rubber tubes arranged side by side vertically in a support frame of hard rubber. An antimony lead grid for collecting the current is provided with lead rods running into the centre of the tubes for the full length. The tubes are filled with the ingredient for forming the active material—mostly red lead (PbO)—and this is then reduced to peroxide of lead, electrochemically, thus forming a positive plate.

The ordinary "Pasted" type of negative is used in combination with this plate in making up the cells.

The Edison storage battery (Class B) uses nickel oxide as active material in the positive plates, and iron oxide in the negative plates, immersed in an electrolyte of caustic soda.

The positive plates are made up of perforated steel tubes containing nickel hydrates for forming the active material, the tubes being carried in a steel frame or grid.

The negative plates consist of perforated steel envelopes containing iron oxide. The envelopes are made of two perforated steel sheets forming pockets between them for holding the active material.

General Comparison of Types: Lead type. *vs.* Edison type.

(*a*) Discharge voltage.

The average discharge voltage per cell for the lead battery at the three-hour rate of discharge is generally about 1.84 volts per cell for the "Pasted" type of plates, whereas the average

voltage for the Edison battery at the three-hour rate of discharge is, I believe, in the neighborhood of 1.2 volts per cell.

Therefore, to obtain the same average voltage during discharge given by a lead battery of 120 cells, there should be required 192 Edison cells.

(*b*) Space required.

In ordinary submarine design the floor space or projected area occupied by the battery is usually more important than the cubic contents. The space required for the Edison battery has until recently been more than that required by the "Pasted" type of battery for the same power.

(*c*) Weight.

The weight of the Edison battery is understood to be greater than the weight of the "Pasted" type of battery for the same power, though as some of the special requirements necessary with the lead battery, such as lead lining of battery spaces, are not necessary with the Edison, all this difference in weight may disappear.

(*d*) Efficiency.

The efficiency in ampère-hours for the lead battery is approximately 0.9 and for the Edison approximately 0.75. The efficiency in watt-hours for the lead battery is approximately 0.76 and for the Edison approximately 0.55. Gasing occurs much earlier in the Edison battery cell during charge, and the potential drop during discharge is greater for the Edison cell than for the lead type of cell.

(*e*) Life.

The life of the Edison battery is greater than that of the ordinary "Pasted" type of cell, but the manufacturers of the "Ironclad" types now claim a life about equal to that of the Edison battery.

(*f*) Cost.

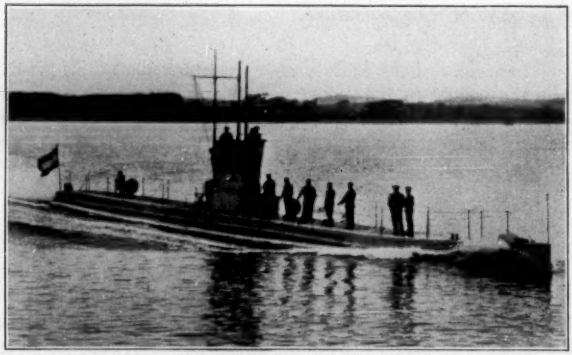
So far the cost of the Edison battery is far greater than the lead type, though, with its greater life, the greater cost may be claimed to be justified.

In designing a purely military weapon such as the submarine it is a grave question in my mind whether durability must not definitely be sacrificed for capacity, unless both can be gotten.

A large radius and speed are more desirable than length of service, which can be provided for by providing more boats, so that when one is withdrawn another may be put in its place, or by providing spare batteries for the boats in service.

Electric Propulsion on the Surface.

Owing to the mechanical difficulties involved in large reversible Diesel engine plants, it may be found advisable to design for a purely electrical propulsion—surface as well as submerged—using Diesel-driven generating sets, or turbine-driven generating sets



Submarine *Atropo*, Italian Navy (Krupp type.)

driving motors on the surface. The present difficulty in the way of such an installation is the size of direct-current motors required for constant duty on the surface.

To save space and weight, voltage up to 500 volts would suggest itself as feasible, or, as a compromise, to use 500 volts for surface running and 250 volts when running submerged, which would involve practically the same voltage as at present used on submarines.

The electric propulsion would involve one or more direct-current generating plants, and the propeller shafts would be supplied direct from the generators for surface running and from the storage battery for submerged running. The speed control obtainable from such an equipment is ideal.

Some propositions have been advanced for obviating the necessity of a duplicate propelling plant, utilizing the surface cruising engines also for submerged work. One of the most prominent of these, up to date, is the Del Proposto system, proposed by a Belgian engineer of that name.

To quote in part from a paper by Mr. Del Proposto, the system is based on the following principles:

"The compressed air can first be regarded as a fluid with a potential power due to its pressure, and then as a chemical composition. Thus it can serve twice for producing energy: first, in a compressed-air motor, and then as feed for an internal-combustion motor. This twofold use of the same air for producing energy leads, evidently, to a reduction in air consumption per horsepower-hour and a given lesser quantity of air to be stored on board for developing a given quantity of energy, and therewith also a reduction in the required weight of air tanks. Thus we come logically to the following conception of the boat, viz.:

"A boat or submarine diver of which the propulsion on the surface is ensured by an internal-combustion motor, which, during such run, can also actuate a compressor which stores air at high pressure in the tanks. During under-water runs the compressed air, reduced to a suitable compression by means of a reducer, passes first through a compressed-air motor, which need be no other than the compressor before mentioned, if its construction allows it, or one or two cylinders of the internal-combustion motor. Then the air is drawn up by the internal-combustion motor, which under water continues working exactly as on the surface. The air which has escaped from the compressed-air receptacle and drawn up by the internal-combustion motor remains in a closed vessel, but if we take note that this air has not lost its chemical qualities nor its composition, and, therefore, can well serve for the breathing of the crew, it is suitable to let it first escape inside the boat, whence it is drawn by the internal-combustion motor.

"In arranging the escape openings of the compressed-air motor on one of the ship's ends at the side where the crew usually is, and the suction of this motor at the opposite end, we establish inside the boat an artificial air current, continuously ensuring strong ventilation.

"It may be noted that, the escape passage of the compressed-air motor and the suction of the internal-combustion motor taking place in the same connecting tubes, it would be necessary to establish there a receptacle of great capacity, which would serve as regulator, intended to avoid the pressure variations at the entry of the internal-combustion motor. In the above-indicated arrangement the whole inside of the boat acts as intermediary tank, and, consequently, the unchangeability of the pressure could be easily maintained. Seeing that the air which serves for the production of energy is used for ventilation of the boat, we have thus an automatic renewal of air without recourse to special apparatus."

I believe the construction of a boat embodying these principles was undertaken, but I am of the impression that its advantages were not all that had been expected. It serves, however, to indicate a possible line of solution, and one which would be desirable if it could be attained.

There have recently come forward several propositions of a somewhat different character, but a proven installation has not yet been produced.

Propellers.

One of the most difficult problems to solve in connection with the design of a power plant for submarines—in fact, a problem without exact solution—is the design of a propeller suitable both for surface and for submerged navigation. There are two conditions to meet, which call for two distinct propellers. Broadly speaking, the first condition is to obtain a certain speed with a certain resistance to propulsion on the surface; submerged, the speed may be the same, but the resistance has increased, because the body to be pushed through the water has increased in volume and has changed shape. It is impossible to have two distinct propellers, and a propeller capable of having its pitch mechanically changed to suit conditions for the sizes now used in submarines has proved difficult to obtain in practice and of less efficiency than a compromise propeller to meet both conditions.

We are therefore driven to the design of a propeller to meet both conditions as near as possible. To do this we must decide which one is to be favored. Either the surface high or cruising speed or the submerged high or cruising speed can be favored,

according to whether we are limited in obtaining power units large enough or in carrying fuel or storage battery capacity.

A safeguard is to design the propeller with an excess of area to make up for errors due to the non-fulfilment of the true pitch in both conditions and to the increase in slip due to the propeller turning faster to meet the increased resistance submerged, owing to the pitch of the compromise propeller being smaller than the pitch required for surface work. Hence the speed load curve of the electric motor should be higher in point of revolutions per minute than that of the internal-combustion engines. But this is not always possible, owing to the characteristic curve of E.H.P. required at different speeds, which is low in point of power at low speeds, compared with the engine load speed curve, which is nearly a straight line, and one has to keep the speed of the motor lower than the speed at corresponding power of the engine in the range of low speeds in order to meet the ship's E.H.P. curve.

Thus, given the engine's speed load curve, the safest course seems to be to design the motor so as to be correspondingly lower in speed for equal power in the range below half load, and higher in speed than the engine at corresponding powers in the range above half load. Then design the propeller with pitch between the pitches required for two propellers designed for each condition separately, with an excess of area and favoring the condition where there are deficiencies, and, finally, making the propellers with adjustable blades so as to be able to modify the pitch during the trial trip.

This is my idea of meeting conditions, subject to further observations during trials to come in order to discover points open to correction. Past performances only, compared with future results, can point out the most effective way for meeting and overcoming the difficulties in this line.

Safety vs. Efficiency.

The tendency of the United States Navy Department's requirements is in the direction of multiplicity of safety devices and escape hatches, greater water-tight subdivision, etc. While this may increase efficiency by giving the crew greater confidence, additional hatches are really a source of danger, and close subdivision interferes with economical arrangement of the interior.

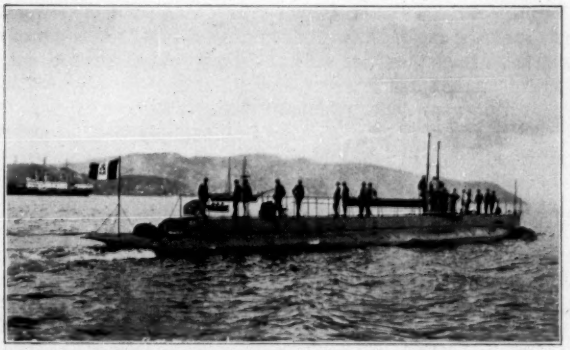
I believe the dare-devil type of man who would naturally

choose submarine service would rather have more effective means for dealing with the enemy and take any reasonable chance on his own safety.

Of course, the Navy Department, under a government such as ours, has to keep the political and public-opinion sides of the question in mind.

Depth of Submergence.

Heretofore all United States submarines had to be subjected to a test depth of 200 feet from the axis, while all foreign submarines have been contented with 40 metres. This, in itself, is



Submarine *Giacinto Pullino*, Italian Navy (Cavallini type).

a penalty on the design of United States submarines, adding, as it does, to the weight of the hull and so increasing the size and cost of a given type of boat.

At the present time the opinion seems to be growing in the United States service that a test submergence depth of 150 feet is sufficient. This means probably that, with improvements in design and growing familiarity with the handling of the vessel, the submarine operators are becoming satisfied that they will be able to avoid accidental submergence beyond this depth if they can check the sudden downward movements at all, and, if they cannot stop her before reaching 150 feet, the chances are they could not before reaching 200 feet, anyway, and therefore adopt 150 feet and save weight for other purposes.

As I understand it, the 200-foot test was originally based on consideration of the depth along the Atlantic coast, ten or fifteen miles from shore, on the theory that a vessel might go to the bottom and still be O. K. if she could stand 200 feet.

As in all other types of naval ships of war, the submarine has two general rôles, defensive and offensive.

Defensive Operations include:

Harbor defence, which, at the beginning of submarine development, was regarded as a primary duty.

Coast defence, an amplification of harbor defence, rendered possible by increase of radius of action and habitability, in virtue of which the submarine may be used to prevent landing in force or other operations along the coast anywhere within limits, equal, roughly, to nearly half their radius of action.

Offensive Operations include:

Destruction of vessels with which the enemy attempts to either hold or control the sea or to carry on military operations.

Attacking the enemy's ships and ports.

Operations in conjunction with the fleet on the high seas.

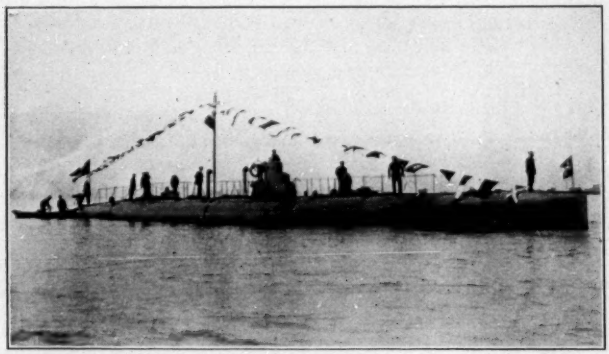
On account of the extensive coast line of the United States, submarines in number seem essential for use in *defensive operations*.

On account of the geographical location of the United States, the value of submarines for attacking enemies' ports is, for oversea enemies, smaller than is the case with European powers. In their use for the destruction of vessels with which an enemy attempts to hold the sea or for use in conjunction with the fleet, a type of boat somewhat different than that required for the strictly defensive operations would result.

From the point of view of the United States, it would seem that the desideratum is an adequate number of submarines that will actually do what is required of them theoretically; *i.e.*, some for defence near our home ports and bases, and some for operation with the fleet on broader defensive lines. To be able to obtain an adequate number it is essential that the necessary features be obtained with the least possible displacement and at the least possible cost.

For the protection of the harbors on the east and west coasts of the United States, it has been estimated by a naval authority that there should be a group of five coast defence submarines and one suitable tender stationed at each of the harbors and places which are considered worthy of protection for strategical reasons.

It has been estimated that for the proper protection of the east and west coasts of the United States there should be a total of fifty-five coast defence submarines on the east coast and a total of forty-five coast defence submarines on the west coast. It is intended that these submarines be based on mobile tenders



Submarine *Fisalia*, Italian Navy (Laurenti type).

located substantially as follows, one group of five boats operating from each base:

East Coast.—Bar Harbor, Me.; Portsmouth, N. H.; Gloucester, Mass.; Provincetown, Mass.; Point Judith Breakwater; New York, N. Y.; Delaware Breakwater; Norfolk, Va.; Charleston, S. C.; Key West, Fla.; Pensacola, Fla.

West Coast.—Port Townsend, Wash., two groups; Columbia River, Ore., two groups; San Francisco, Cal., two groups; Santa Barbara, Cal., one group; San Pedro, Cal., one group; San Diego, Cal., one group.

No mention is made above of submarines for the defence of our oversea possessions, such as the Panama Canal, Atlantic and

Pacific ends, Guam, Hawaiian Islands, and the Philippines, but it is believed that at least one mobile tender in combination with a group of five coast defence submarines would be needed in each such locality, with probably several groups in the Philippines, to prevent effectually the operation of a hostile fleet in these waters.

One occasionally reads of submarines of destroyer speed, which to the layman appear entirely practicable and to the military man highly desirable, but to the submarine man it seems impossible, and certainly is to-day, meaning, as it does, about thirty knots on the surface.

The advent of the large sea-going type of submarine is a logical development in submarines, and there seems little doubt but that in the future two distinct types of submarines will be recognized to be needed; namely, a small type designed for harbor defence or coast defence, and a large type or sea-going submarine, capable of accompanying the fleet even to the waters of the enemy's country and supporting the battle fleet in a fleet action.

The essential features of the small type have already been worked out and are in successful operation and generally known, so that new development of the equipment of these boats will naturally be slow, but the conditions that the sea-going type must meet give an opportunity for increased development, particularly in the propulsion plant, both for surface work and submerged operation.

The present type of submarine, of which our navy has a considerable number, has a surface speed of from 12 to 14 knots, with a radius of action at 9 or 10 knots of from 1500 to 4500 miles. Such boats range from 250 to 550 tons displacement submerged, and have fairly small reserve buoyancy.

For a purely defensive type of submarine the 4500-mile radius is, in my opinion, entirely unnecessary, and requiring it results in a boat of considerably greater cost and size than is necessary to perform the work which it is intended to do and is capable of doing.

The sea-going, fleet speed submarine, to be used in conjunction with the fleet, is quite another matter, and the provision of long radius of action is not only justifiable, but necessary.

Considerable prominence has been given recently to the giant

submarine projected by our Navy Department. What is really aimed at is a sea-keeping submarine for service with the high-sea fleet.

Public policy prevents my entering into details of the vessel desired, but there is no impropriety in my discussing briefly the general principles of such a design.

Foreign powers, by which I mean England and France, have undertaken, but not yet completed, a submarine of some 18 to 20 knots surface speed and with submerged speeds of 13 or 14 knots.

Complete details of such vessels are not available, but they naturally lead to dimensions far in excess of those of submarines now in our service.

For submarines of the coast or harbor defence type it is usual to have a hull of circular cross-section, sometimes modified toward the extremities into an ellipse, with its major axis horizontal or vertical, as required by conditions.

After exhaustive investigation I am convinced that for vessels of moderate speed requirements this form is, all things considered, the best.

When, however, one approaches the sea-keeping submarine he is confronted by another problem. Here, in order to obtain a surface speed equal to that of the fleet—of, say, 20 to 21 knots—the form given by the conventional type of circular cross-section is not suitable, and one must approach more nearly to the conventional ship-shaped form.

This results more or less logically in the double-hull type, with a circular hull within, designed to withstand pressure, and a ship-shaped lighter hull without.

The conditions of service that such a boat must fulfil demand greater conditions of habitability, free board, deck space, etc., than are necessary in the coast defence type. The percentage of reserve buoyancy must be higher than in the smaller boat to insure ample seaworthiness, and the stability should be greater.

The double hull is not always entire: *i.e.*, in some types the double hull ceases to exist at the forward and after ends, and is merged into the single ship-shaped hull.

Owing to the pressure that it must stand, the submarine's hull must always be proportionately heavier than a surface type, and when a double hull is necessary this excess of weight becomes greater still. It therefore requires but short consideration to see

the difficulties that must be overcome to give a submarine destroyer speed, with its greater hull weight and its two systems of propulsion.

Operations.

All of the submarine operations so far chronicled during the present European war may be said to be in the nature of naval raids, as distinguished from strictly tactical evolutions. The surface radius of even the smaller types of submarines is quite sufficient for any of the raiding operations of which we have read.

Undoubtedly the submarine proceeds on the surface to a point where previous reports indicate that the enemies' ships are, or are apt to be, then comes to the awash conditions and waits. If his quarry is sighted, he may submerge and await him, or so direct his course as to cross that of the enemy.

The fact that he was a long way from his base was, at least in the early days of the war, an undoubted benefit to the submarine, as no one suspected him of being there, but, even if they did, his invisibility when submerged and his close approach to it even on the surface make him reasonably safe, though on a long run the crew might not be luxuriously comfortable.

It is quite possible that the submarine will continue to be most heard from in this form of operation, to which its inherent qualities are well adapted. The moral influence of this hidden danger and its constant wearing away of a near or far blockading fleet or one patrolling the seas to keep them open, as the British fleet is doing in this war, is not to be underestimated in its effect on the fleet itself or the public whom the fleet represents.

I have it on very reliable authority that the Germans in the present war, in some instances, have used a fishing boat or some other surface vessel, pretending it to be a mine-layer, as a decoy.

The question of the tactical use of the submarine in groups is, however, of importance and will become increasingly so. The maximum range for successful attack of a submarine is limited by the circle of visibility. The sea horizon, viewed from a periscope twenty feet above the surface, is just 10,000 yards. At this range the horizontal angle subtended by a 600-foot target is a little under one degree. When the periscope height is three feet above water the sea horizon is distant 4000 yards, and when one foot exposed becomes 2200 yards.

The practical difficulties of finding and then firing at specks on the horizon are so many as to compel the submarine to take advantage of her invisibility and immunity from gunfire, to push the attack to close quarters—2000 yards or less—or, if unable to do this, then to hold fire until more favorable opportunity offers.

What I shall give you now as to submarine tactics is quoted in some part from a paper prepared by one of our best submarine officers, and may be said to have the weight of experience behind it.

Before entering into a discussion of the tactics of submarines, one should first consider the various means of communication between submarines and scouts or shore stations before sighting the enemy, and between submarines themselves after sighting the enemy.

On the surface the submarine has the following means of signalling, the order of their estimated value being as given:

Radio (day or night).
Searchlight (day).
Searchlight (night).
Shape signals (day).
Flag signals (day).
Wigwag or semaphore (day).
Very's start (night).
Wigwag torch (night).

Submerged the submarine has the submarine bell signal apparatus, and, more recently, the Fessenden oscillator, which performs the same function even more satisfactorily.

The submarine bell can be used between submarines or between submarines and tenders or shore stations, at distances varying with the attending circumstances. Under the most favorable conditions (*i.e.*, all machinery stopped) signals may be exchanged at distances up to eight miles with fair success. With machinery running, and under the most unfavorable conditions (*i.e.*, boats running in opposite directions), signals may be exchanged at distances up to one-half mile.

Of the various means of signalling, none can be used in the face of the enemy without danger of betraying the presence of the submarine group.

As the submarines of the types at present in existence have a submerged speed probably inferior to the surface speed of the enemy, and as in that case the enemy can keep out of torpedo range, it is important that no signals be sent that might give the enemy warning of the presence of submarines.

It may be wise to here give definitions to the terms "light condition," "awash condition," and "submerged condition," so as to explain later references.

A submarine in the "light" condition has all of its water-ballast tanks empty and has its cruising bridge rigged.

A submarine in the "awash" condition has only those water-ballast tanks empty which are habitually kept full when running submerged. The fore-and-aft trimming tanks and two smaller tanks, called the auxiliary tank and adjusting tank, are filled with just enough ballast so that when the main ballast tanks are filled the boat will be immediately ready for running submerged without further adjustment of ballast. The quantity of water in the trimming tanks and in the auxiliary and adjusting tanks, in the "awash" condition, is so small, in comparison with the total ballast, that the submarine has practically the same stability and safety as when running "light." In the "awash" condition a small section of the bridge may be kept up for the lookout, and the conning-tower hatch may be kept open and the radio rigged.

A submarine in the "submerged" condition has the ballast tanks and other tanks so filled that there still remains a small reserve of buoyancy (0 to 800 pounds) and is all ready for submerged running.

For the purpose of tactics, submarines may be divided, according to their capabilities, into three classes, viz.: harbor defence, coast defence, and sea-keeping offensive submarines.

The tactics of a group of harbor defence submarines are simple. Their limited submerged radius and speed do not enable them to operate far from the entrance of the harbor which they are protecting. The lack of reliable under-water communication makes it impossible to change plans of action, once their group is submerged, without giving the enemy a clue as to the submarines' whereabouts. Any form of under-water signalling device in use at the present time can be accurately located in direction by the enemy. The apparatus for locating the direction of submarine signals is installed on practically every modern ship.

For this reason alone the detailed plans for a group of harbor defence submarines must be made explicit enough to cover in advance every plan of an attack by a determined enemy.

Each boat of a group would be assigned a certain area outside of the harbor as its zone of defence, these zones to be so selected that all approaches to the harbor are protected, and to be at such a distance from the point of defence that the enemy will never come within gun range.

Most of our harbors lend themselves naturally to such a method of defence by the form of the channels leading to them or by the presence of islands in the vicinity. A harbor defence group, having received warning from scouts or shore stations of the movement of the enemy off the coast, immediately proceeds to the entrance, leaving the tenders inside the harbor. Submarines anchor in the "awash" condition, radio up, in the centres of their zones, and keep a lookout for the enemy. By subdividing the total area outside of each harbor into small squares and using short code words to designate squares and directions, scouts in touch with the enemy can easily keep the waiting group of submarines informed as to the enemy's movements.

The waiting submarines, having been warned that in all probability the enemy will pass close to their harbor, are prepared and immediately get up their anchors and submerge as soon as smoke appears on the horizon.

With a moderate amount of their periscopes exposed, a submarine can easily see a large ship in clear weather for a distance of seven or eight miles. The submerged group, each boat in its zone, remains stationary until the movements of the hostile fleet are definitely ascertained. By the arrangement of the zones the enemy must pass close to one submarine; the other boats would then move over toward the enemy at such speeds and with just periscope exposure to enable them to get within torpedo range without detection. Once within torpedo range, they keep their periscopes exposed and make all speed possible to get within easy torpedo range to fire their torpedoes at that part of the enemy's formation previously assigned to them. In this last manœuvre each boat would act regardless of the other boats and must take the risk of collision. On this final charge the submarine bells may be rung continuously to assist the submarines to keep clear of each other. Having fired their torpedoes, the boats sub-

merge totally, and reload their tubes if they have spare torpedoes. During the period of reloading they may run at such depths as would enable them to pass under the enemy's vessel, or, if the depth of the water permits, they can rest on the bottom until the reload is finished, when they should return to the surface to inflict such further attack as is possible. A submarine, having exhausted her supply of torpedoes, has still a most formidable weapon in her ram. This has been proved in several instances where accidental ramming has occurred.

The harbor defence group, having exhausted its means of offence, should return to the tender, submerged, if necessary, under cover of darkness, to replenish torpedoes and storage batteries.

For the night defence of the harbor submarines remain on the surface in their zone, being used in this manner most effectively as surface torpedo boats. The tactics on the surface as torpedo boats are similar to the tactics employed in surface torpedo craft, though as such they are somewhat less efficient, owing to their lesser speed.

The distinction between a coast defence and a harbor defence submarine lies principally in the greater submerged and surface endurance, the greater submerged and surface speed, and the better habitability conditions of the coast defence boat, which gives it a wider range of action than its smaller sister.

It will be noted that in the defence schemes for east and west coasts submarines of the coast defence types were referred to. A coast defence group will accomplish with greater effect the same duties that are now accomplished by the harbor defence group.

In considering the tactics of a group of "coast defence" boats it is assumed that information has been received from reliable sources, scouts or shore stations, that the enemy's fleet is approaching our coast with the evident intention of seizing a base or of landing a force. The group proceeds at its highest reliable surface speed, in column, in the "awash" condition, with radio up, to intercept or to come in contact with the enemy. The submarine, with its low hull, can easily distinguish the masts and other characteristics of a vessel when the submarine cannot be seen at all. On sighting the smoke or masts of the hostile fleet, and having approximately determined its course, the entire group immediately submerges, after rigging down the radio, and proceeds sub-

merged at about one-half mile distances, in the general direction of the enemy, at such speeds and under such general instructions as may have been previously issued by the group commander. The boats of a submarine group, submerged at one-half mile distances, can easily keep clear of each other.

They should then manœuvre to keep a position on either bow of the enemy's column in order to insure their getting within torpedo range before being sighted. By "torpedo range" is meant 2000 yards. This approach must be totally submerged, with an occasional "porpoise" or periscope exposure of short duration. When within torpedo range periscopes should be exposed enough to keep an easy bearing on the enemy, and the speed increased as much as possible to arrive within easy range (between 500 and 1000 yards) before the enemy has time for a concerted manœuvre. Each submarine fires its torpedoes at the parts of the formation previously agreed upon, totally submerges, reloads as soon as possible, and returns to the attack. Using 18-inch torpedoes capable of angle fire, a four-tube boat should set one torpedo to run five degrees to port of her keel, two to run straight ahead, and one to run five degrees to starboard of her keel.

The movements of each individual boat in contact with the enemy will be dependent on the enemy's formation. A table showing the proper bearings on which to fire torpedoes with maximum changes of hits has been compiled for every possible formation, and is readily understood by submarine officers. It is not to be hoped that every shot will be a hit, nor that every ship of the enemy's force will be disabled. It is to be reasonably expected, however, with the above method of firing, enough damage will result from the discharge of twenty torpedoes to prevent the enemy from accomplishing its purpose.

With accurate knowledge of the enemy's whereabouts off the coast, two or more coast defence groups may be dispatched to the probable destination of the enemy to deliver an attack as shown above.

Submarine groups having exhausted every means of offence, including the torpedoes and ram, should withdraw submerged at low speed or lie on the bottom, if that is possible, until nightfall, and then return to the base of supplies under cover of darkness, charging their storage batteries on their way to the base.

All attacks so far have been assumed at an enemy which is moving. Should the attacking group discover the enemy at anchor, landing troops or establishing a base, it should continue as above outlined, totally submerged, with only an occasional "porpoise" of short duration, until well within torpedo range, when the periscope should be kept exposed until the torpedoes are fired at easy range at prearranged parts of the enemy's formation. No special difficulty should obtain in passing the line of the enemy's scouts or pickets with the submarines running totally submerged with occasional "porpoises."

After the reload of torpedoes the submarines must act absolutely independently, as it is probably impossible, with the present lack of under-water signal facilities, to communicate. In all cases the chief duty and aim of the group commander must be to bring all of his group *into contact with the enemy and within torpedo range at the same time.* Having done this, it is up to the individual commanding officers to produce the desired results.

A "sea-keeping offensive" submarine has been defined above as a submarine which can keep the sea, ready for duty, under all conditions of weather, for considerable periods. Such a submarine group could obtain its supplies from vessels of the fleet which it accompanies, and be as mobile as any unit of the fleet.

The tactics of such a submarine group after contact with the enemy will be the same as the tactics already described for harbor defence and coast defence submarines in contact with the enemy. The problem of manœuvring such a group into contact with the enemy, or, to state the case more accurately, the problem of manœuvring the enemy's fleet into the "submarine danger area," must be solved by the commander-in-chief.

As an illustration of the use of one or more offensive submarine groups accompanying a fleet, let it be assumed that the submarines have a surface speed capable of cruising with the fleet at any speed that may be required to keep up with the fleet. Let it also be assumed that the submerged speed and the radius of the submarines is about twelve knots for one hour, or about eight and one-half knots for four hours, or about five knots for fifteen hours—all within the range of present-day possibilities. Suppose, also, that in the cruising formation submarine groups take position on either flank of the fleet. The submarine groups are in the "awash" condition, ready for instant use. The commander-

in-chief, having received information from his scouts of the presence of the enemy, or having sighted the enemy, should immediately send his submarine groups "awash" off on a bearing previously decided upon, and then endeavor to manœuvre his opponent into the area occupied by the submarines.

The submarines may remain "awash" until the enemy's smoke or masts are sighted. If our commander-in-chief possesses a superior speed, he can choose his own situation, and, having patience, can eventually bring the enemy into the submarine area. In this case submarine groups should manœuvre "awash" or "submerged," as is necessary to keep out of the enemy's sight, and endeavor to attack the enemy's formation as soon as possible without interfering with the movements of the commander-in-chief.

If our commander-in-chief has the inferior speed and inferior force, and if the enemy is determined to bring about an action, the problem of making him cross a submarine danger zone is greatly simplified. The appearance of several groups of submarines within or very close to the enemy just before a general gun action would undoubtedly cause the enemy to so alter his plans and formation that he would be at a temporary disadvantage. Even if all the torpedoes shot missed, the effect on the morale of the enemy would be sufficient to give our commander-in-chief a temporary advantage. Most of the important fleet actions have been fought in sight of land or close enough to shoals to cause the movements of the vessels in action to be somewhat restricted as to courses. In cases of this character the commander-in-chief can so station his submarine groups as to increase the chances of forcing the enemy into the submarine danger area.

If the commander-in-chief desires to withhold the submarine attack until after the gunfire, the submarine group should be kept in the background within easy radio signal distance, but in doing this the commander-in-chief will probably find that it will be more difficult for the submarine groups to make a successful dash across the space between the engaged fleets, due to the inferior speed of the submarines submerged. Ships of the enemy that are already disabled would in such cases become easy prey for the submarines. Submarine groups accompanying a fleet are decidedly offensive weapons and of the greatest value when used just preceding a general gun action.

A ruse which might assist in forcing the enemy to keep away from certain areas and thus increase the chances of making the enemy cross the submarine danger zone would consist of having the fast scouts of the fleet drop numerous poles, properly weighted, to float upright in the water, and painted to look like a submarine periscope. These same dummy periscopes floating out of a harbor with an ebb tide or dropped outside by scouts or fishermen may greatly influence the movements of an enemy sighting them. It is extremely difficult to distinguish between dummy and real periscopes, for it is easy for a submarine to lie submerged and stationary with only a small amount of periscope showing.

Something of this kind has been successfully done in fleet manœuvres several times.

The night manœuvres of a submarine craft are the same as for surface torpedo craft, and the same tactics apply. As there is no possibility of "torching," and as the hull is so low in the water, it is extremely difficult to pick them up at night, even in the full rays of the searchlight. The manœuvres off Provincetown in the summer of 1911 demonstrated that in nearly every case the submarine could come within easy torpedo range of the enemy at night without detection. In a night attack submarines should remain in the "awash" condition, so that in case of self-preservation, or to pass through a picket line, the submarine can quickly submerge.

It may very well be that while I have been talking to you the submarine has again demonstrated its effectiveness, but whether so or not, it has already done enough to make its power felt.

A weapon to which there is no defence and no reply is one not to be lightly put aside, and no navy wanting in adequate number of submarines is complete.

Street-car Tires of Rubber. Anon. (*Sci. Amer.*, cxi, No. 12, 223.)—In order to reduce the noise of street cars, and particularly the flat-wheel nuisance, it was suggested, at a recent meeting of the Tramways Association, in Newcastle, England, that street cars be provided with rubber tires. It was argued that the wear on the rails would be greatly reduced, and the life of the rubber tire would exceed that on motor trucks and 'buses, which are credited with an average life of 20,000 miles. Further, it was stated that a higher rate of speed would be possible with a flexible tire.

Ruby Color in Glass. A. E. WILLIAMS. (*Trans. Amer. Ceram. Soc.*, xvi, 284.)—Ruby glass is obtained by using as coloring agent copper, gold, selenium, or flowers of sulphur; the metals are usually found in suspension as colloids. Recipes culled from the literature on the subject are given for gold, selenium, and sulphur rubies, but the author's experiments refer to copper ruby glass. Formerly this was made by the process of flashing, which consists of placing a very thin layer of colored glass on a surface of colorless glass of normal thickness, special skill being required to blow the layer to uniform thickness in order to obtain uniform color. Now, however, ruby glass is made by pressing in moulds and reheating. The color should not be developed until the glass is reheated. Highly fluid glasses are found to "color out" quickly, viscous glasses slowly. Substitution of lead or soda for lime increases the rapidity of color development, lead more so than soda. High silica content (4 to 4.5 mols.) is necessary to give sufficient viscosity and to obtain good color; low silica tends to produce brown or black colors and opacity. With high silica in lime-potash glasses there is a tendency to streakiness, which can be reduced by small quantities of lead oxide and by remelting. Iron and manganese are detrimental to a good red color. Density of color is apparently increased by increase in temperature. The following formulæ were found most suitable for good ruby glass, 1 per cent. cream of tartar being added:

Na_2O	0.102	....	....	0.100	0.100	Equivalents.
PbO	0.627	....	....	....	....	Equivalents.
K_2O	0.202	0.536	0.536	0.536	0.536	Equivalents.
SiO_2	3.33	4.57	4.00	4.00	4.57	Equivalents.
CuO	0.067	0.023	0.023	0.023	0.023	Equivalents.
SnO_2	0.018	0.041	0.041	0.041	0.041	Equivalents.
B_2O_3	0.073	....	....	....	....	Equivalents.
CaO	....	0.44	0.44	0.34	0.34	Equivalents.

Study of the General Properties of Tool Steels. DENIS. (*Rev. de Métallurgie*, xi, 569.)—The multiplicity of tool steels all put to the same use and the differences in the results obtained on the same brands of steel in different works appear to indicate variations in the thermal treatment, owing to the neglect of carrying out systematic tests previous to the use of the steel. A certain number of brands of tool steels seem to be preferred by a large number of works, but on different grounds. To determine if this preference is based on real grounds, the author has made, in the workshops of the French Army and Navy, a systematic study of the properties of tool steels, and divides his report into three parts: (1) General considerations of the methods of testing tool steels and of the thermal treatments which may be applied to them. (2) Various tests made on the principal brands of tool steel used in industry, with the object of determining the best thermal treatment corresponding to any of their various uses. (3) Conclusions from the tests. Characteristics of the steels studied, from the point of view of their constant use.

PAINTS TO PREVENT ELECTROLYSIS IN CONCRETE STRUCTURES.*

BY

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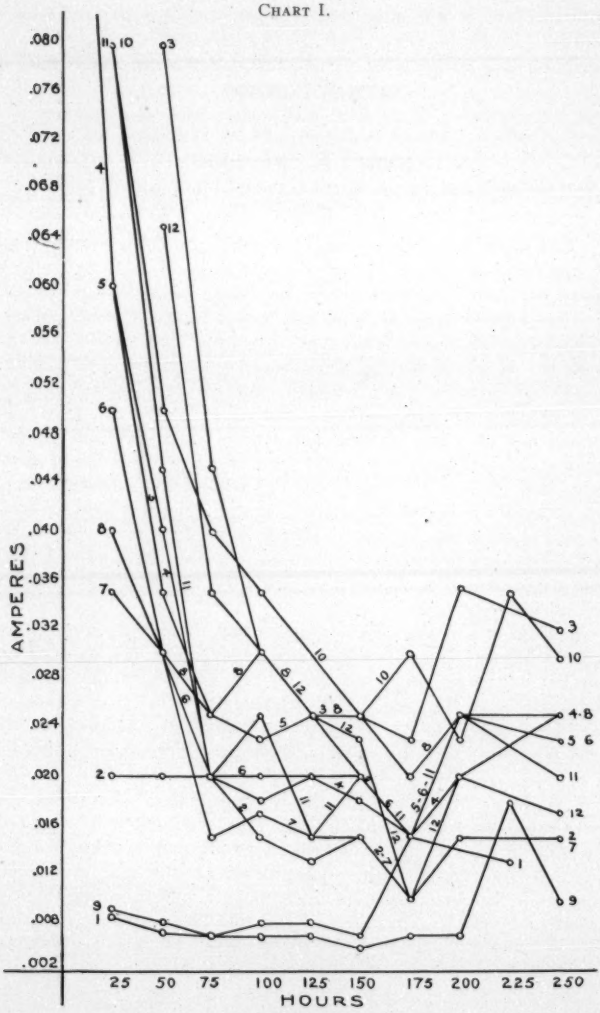
THE use of protective paints upon metal that is to be embedded in concrete structures, in order to prevent any damage which might be caused by electrolysis, has been heretofore proposed. No tests have been made, however, so far as the writer is aware, which have determined what type of coating is best suited for the purpose. It would appear, from first consideration, that a paint capable of forming a film of high electrical resistance would be most efficient for the purpose. Such films, however, generally present a high gloss surface and are apt to prevent the proper bonding of the concrete with the painted metal, thus doing more harm than good. It is chiefly for this reason that engineers have not generally adopted the use of paint upon reinforcing metal. In the experiments presented herein, a method for overcoming this objectionable feature of insulating paints is described, and data are presented on the relative insulating and bonding values of several different types of paint.

Corrosion Causes.—Before describing these tests it might be well to briefly review, for the benefit of those not thoroughly familiar with the subject, some of the conditions upon which metal corrosion depends. The ordinary forms of iron corrosion have been found to be due to auto-electrolysis, the presence of segregated impurities being responsible for differences in potential at certain areas, which set up galvanic action and cause solution and the formation of rust at the positive nodes. A similar but more rapid action takes place when an electric current is passed through an iron anode immersed in an electrolyte such, for instance, as salt water. When damp cement contains an embedded iron anode the cement acts as an electrolyte, and the same rusting action takes place, regardless of the fact that concrete contains

* Communicated by the Author.

CHART I.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HOURS

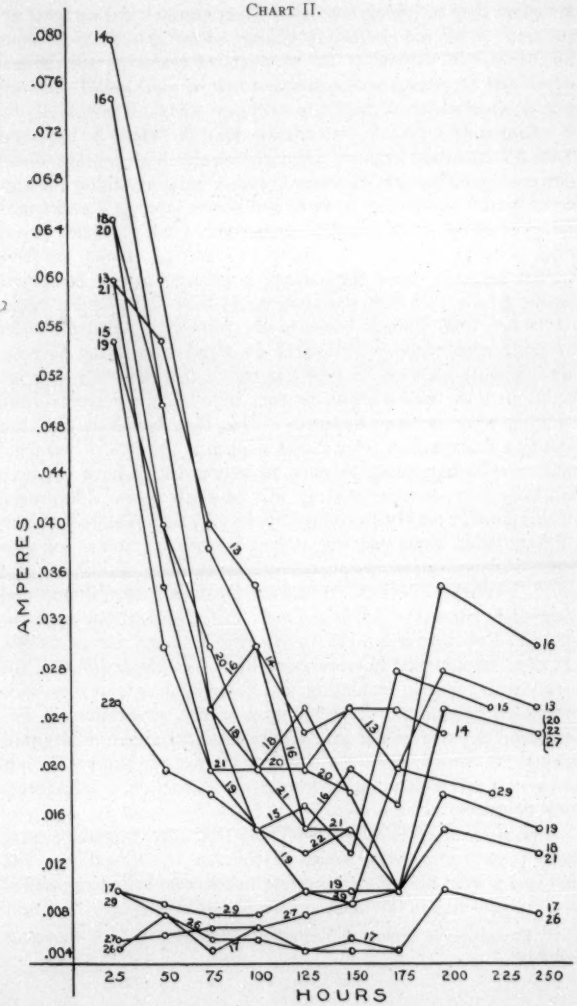
sufficient lime to inhibit corrosion when no electrical currents are present. With the electrolytic change of metal into oxide comes an increase in volume of the products of reaction, and there is developed an enormous expansive force of mechanical pressure, which is sufficient to crack the strongest forms of concrete.

Source of Currents.—Corrosion may therefore be expected, with its attendant results, when sufficiently high voltage direct currents enter the iron of a new concrete building, either through contact with conductors of light and power circuits, contact with water or gas pipes carrying direct currents from grounded power lines, through defective insulation of electrical wiring, or from similar sources. That the damage is greatest to new structures is due to the fact that the concrete is then damp and a better electrolyte than when it becomes dry from age. That examples of reinforced concrete structures damaged from stray currents are not more common may be due to the fact that engineers are active in their endeavors to prevent high-voltage currents from running wild in many localities. This fact, however, does not justify a disregard of what might happen in the future and what may now be happening to some structures which have not been carefully guarded against stray current electrolysis. That much of this damage may be prevented by the adoption of suitable forms of foundation waterproofing, exterior insulating joints for pipe lines, isolation of lead-covered cables entering buildings, and other insulating devices, is shown by Rosa, McCollum, and Peters [1] in what is probably the most valuable contribution to the subject of reinforcement electrolysis that has ever been published. Of equal importance, however, should be the safeguarding of the metal with suitable insulating and bonding paints before it is embedded in cement. The adoption of this precaution, if followed by the use of the safety devices noted above, will guard against the causes which contribute to electrolysis and render our modern concrete structures safe from destruction by reinforcement corrosion.

Preparation of Specimens.—The writer's investigations were made upon two separate series of concrete test cylinders. The first series were made by embedding in concrete cylinders painted iron rods ½ inch in diameter and 12 inches in length. The rods.

[1] "Electrolysis in Concrete," Technologic Paper No. 18, U. S. Bureau of Standards.

CHART II.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HOURS

previous to painting, were thoroughly cleaned from scale and rust. Two coats of paint were then applied, allowing a week's time for drying between coats. The painted rods were then placed in moulds in an upright position, about an inch apart and one inch from the bottom of the moulds. Cement mortar, prepared from one part of Portland cement and two parts of sand, was poured around the rods and tamped into place. After two days' time the moulds were removed and the test pieces were repaired with cement mortar wherever defects were shown.

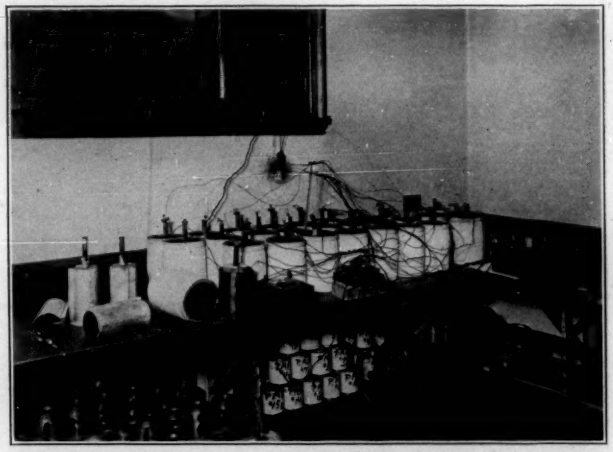
FIG. 1.

Method of Making Good Bonding Surfaces.—In making up the specimens for test it occurred to the writer that the objection to using paints which dry upon metal to a gloss surface and which prevent proper bonding of the cement might be overcome by applying to the painted surface, while it is still tacky (not dry), sharp particles of sand or similar material. Emery powder, abrasives, and fine quartz sand were among the substances tested. When allowed to drain upon a painted rod, the particles become

attached to the paint and dry with it to form a rough surface resembling coarse sand-paper. After thoroughly drying, the particles are solidly embedded in the paint, which thus presents a dull rather than a gloss film. Fine, clean, white sand was found most useful.

Arrangement of Tests.—After aging for a month, the pieces were connected up in parallel and in series with resistance to reduce the voltage from 110 to 30 volts direct current. Current readings were made over a period of 24 hours. The current

FIG. 2.



passing was small. The test cylinders were then placed in a shallow pan containing sufficient water to immerse the lower two inches of each specimen. After a week's test, the cylinders were disconnected and removed from the pan for observation. A few of the specimens showed small cracks near the bottom, where the wet cement had conducted the current to the greatest extent. The cylinders were then placed in separate earthenware jars and again connected up. The jars contained sufficient water to immerse the specimens up to within one inch of their top surfaces. They were left in circuit for ten days and current readings were

made every 24 hours. Cracking was shown by nearly every cylinder which current readings proved to be carrying any appreciable amount of current. The fracture in every case started at the anode, extending radially to the edge of the cylinders and parallel to the electrode, gradually opening up as the tests were continued. The specimens were finally disconnected and removed for exam-

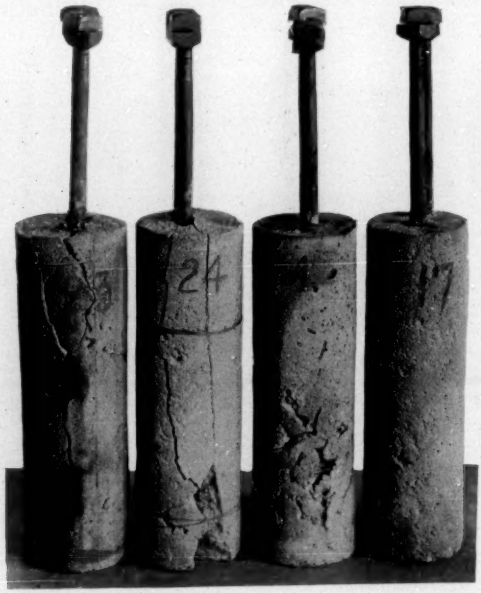
FIG. 3.

ination. Those which had been cracked by the electrolytic corrosion of the metal were easily split into two sections, disclosing the contained electrodes. The others, which did not show any cracking, were parted with a chisel in order to make a comparative examination of the condition of the embedded metal.

Second Series.—In Series II the specimens were made by embedding in concrete cylinders painted anodes ¾ inch in diameter

and 12 inches in length. The rods, previous to painting, were thoroughly cleaned from scale and rust. They were painted with two coats of the same paints used in Series I. The rods were placed in moulds 3½ inches by 8 inches, in an upright position, and the same kind of Portland cement mixture as used in Series I tests was placed around the rods and tamped into place. The

FIG. 4, Series 1.

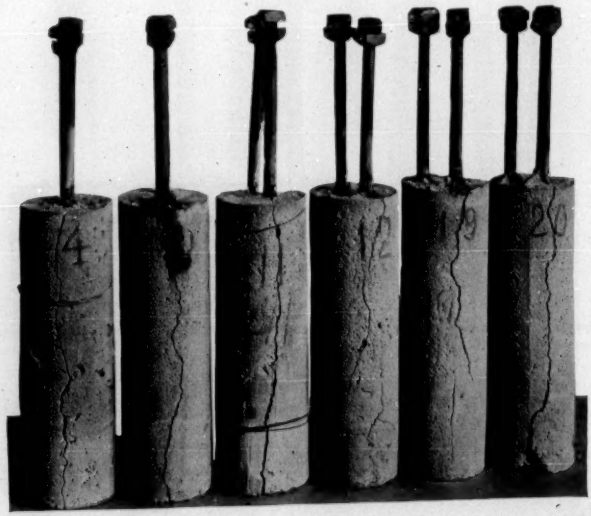


specimens for this series were very carefully prepared and presented a much better appearance than those used in Series I. After setting for two days, the moulds were removed from the pieces, which were then aged for a month. They were then placed in water for 24 hours, and the next day were placed in individual earthenware jars containing sheet-iron cathodes coiled so as to surround, but not touch, the cylinders. The jars were filled with

sufficient water to cover the cylinders up to within one inch of their top surfaces. The specimens were connected up as in Series I. The tests were continued for 240 hours at 30 volts, during which time Nos. 4, 10, 11, 13, 15, 19, and 24 had developed cracks. The voltage was then increased to 55 and continued for 60 hours, at which time the tests were discontinued.

Test of Bonding Value.—In order to determine the comparative bonding strength shown by the various painted rods with the

FIG. 5, Series I.

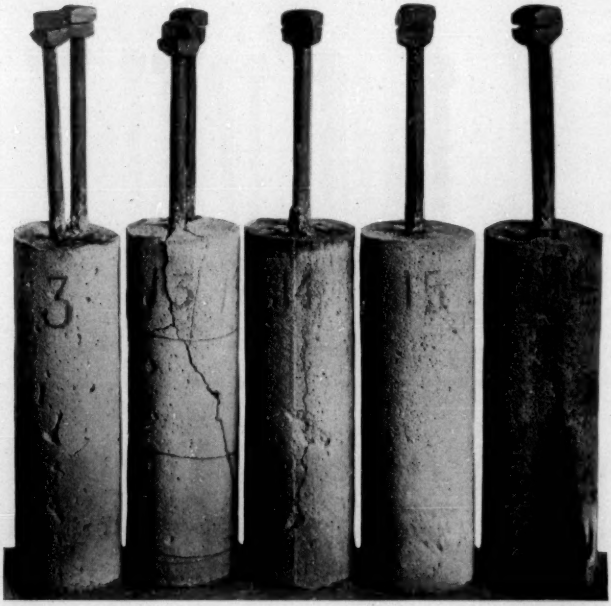


surrounding concrete, a series of test specimens was prepared, exactly duplicating those used for Series II, except that the rods were placed flush with the bottom surface of each cylinder. After aging for three weeks, the specimens were tested in a Riehle testing machine, upon an iron block drilled in the centre with a 1-inch hole. Each test specimen was placed in such a position that the lower end of the contained iron anode would be in alignment with the hole below. Pressure was applied until the painted iron rod

was pushed away from the surrounding cement and the bond destroyed.

Observations on Results.—In the test specimens where cracking had occurred the anodes showed considerable rust, the paint coatings originally applied having been destroyed. On the cathodes in Series I the paint coatings were still intact, although some

FIG. 6, Series 1.

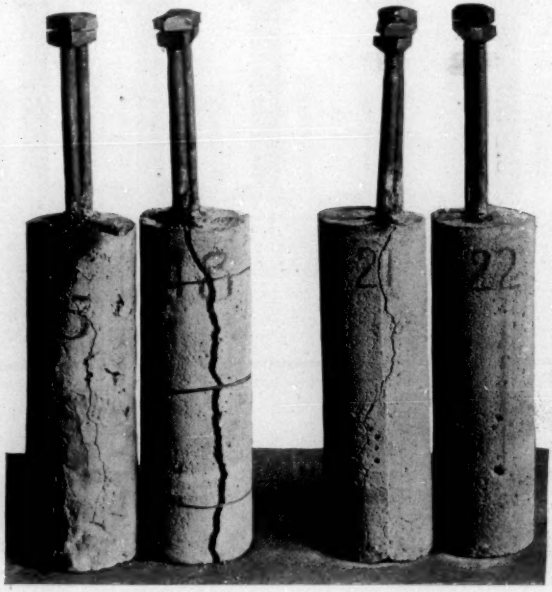


had apparently been affected by the moisture and the hydrated lime in the wet concrete, chalky surfaces being shown. Wherever there were small voids in the concrete, at or around the painted anodes, corrosion was most severe, and at such places pitting was shown. The protective coatings upon the anode and cathode bars embedded in the concrete cylinders which did not

crack and which carried but little current were later found to be in a very good state of preservation.

Incidental Reactions.—The breaking down of a film upon the embedded iron rods was always recorded by a sharp rise in the amperage, due to the decreased resistance offered to the flow of the current between the electrodes. It was also recorded by a fizzing

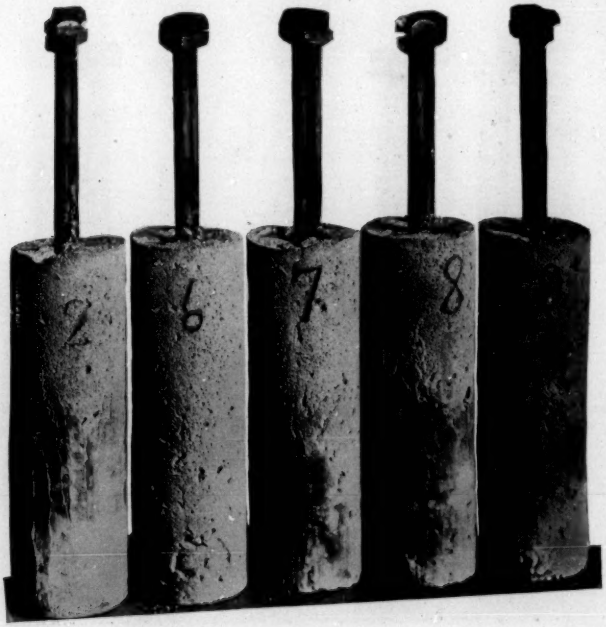
FIG. 7, Series 1.



sound, due to the increased evolution of hydrogen gas developed by the electrolysis of the water in the damp concrete. This gas, issuing from around the iron electrode at the top of the test pieces, generally carried some water with it, and small bubbles were formed, which burst with an audible explosion when a lighted match was placed in contact with them. The hydrogen gas

seemed to have a reducing or softening action upon some of the oxidized coatings, and carried to the surfaces of the cylinders considerable quantities of soft oily products, which deposited around the anode and later hardened in contact with the air. Iron oxide was also carried to the top surfaces of some of the

FIG. 8, Series 1.

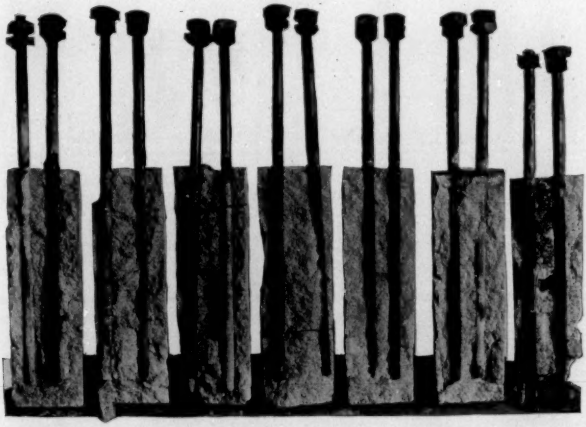


specimens by the action of the gas and water, and was there deposited as a dark brown stain.

Electrolytic Hydrogenation of Oil Films.—That the nature of the paint films has considerable bearing upon the action of the hydrogen gas which was found to be developed during the tests there can be no doubt. In an investigation to determine the cause of the rapid corrosion exhibited by some grades of lacquered

tin food containers, W. H. Walker[2] and Slade[3] have found linseed oil films to act as depolarizers of hydrogen, and Walker points out that such films, if in a semi-oxidized condition, may absorb hydrogen quite as rapidly as oxygen. This may account for the appearance of the oily substances brought to the top of some of the cylinders. Electrolytic hydrogenation may have been effected by the action of the nascent hydrogen in the presence of iron oxide or other pigments which could act as catalyzers. The action was sufficient to produce a product which, although fluid

FIG. 9, Series 1.



when formed, on account of the warmth of the cylinders at the anode where heat was developed by the electrolysis, later became solid when deposited upon the surface of the cylinders. It was in specimens showing such surface deposits that the bond between the cement and steel was the weakest.

Value of Well Dried and Saturated Films.—Walker has also

[2] "Paint and Varnish Coatings as Accelerators in the Corrosion of Metals," W. H. Walker and W. K. Lewis, *J. Ind. and Engrg. Chem.*, 1909, vol. i, p. 754.

[3] "A New Method for Testing Paint Films and Preservative Coatings for Iron and Steel," W. C. Slade, *J. Ind. and Engrg. Chem.*, 1912, vol. iv, p. 189.

referred to the fact that paint films that have been baked, on account of their fully saturated condition, do not act as depolarizers. It would obviously be impractical to bake paint coatings upon most forms of reinforcing metal, but quite thoroughly oxidized coatings, which would probably have but slight depolarizing

FIG. 10, Series 2.

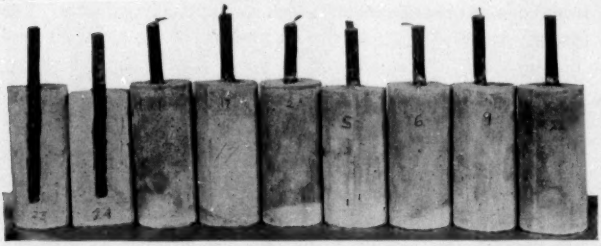
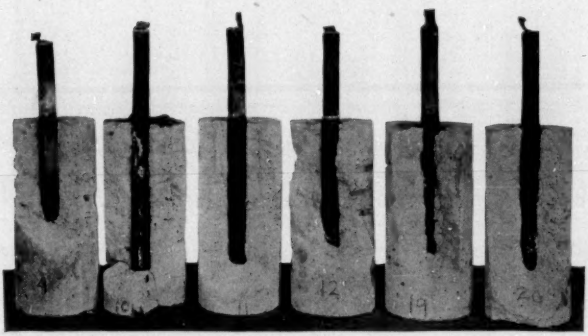


FIG. 11, Series 2.

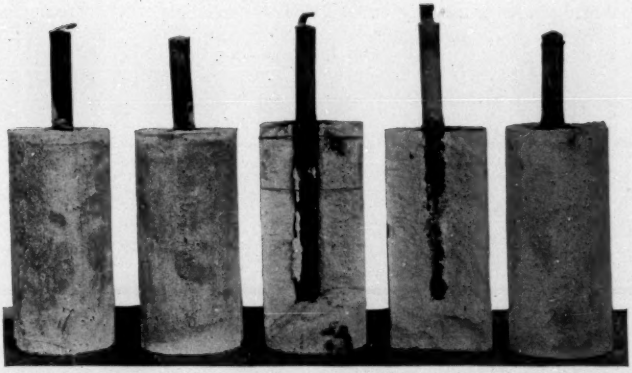


action, would result by allowing a period of 60 days for the drying of oil paints after application to the metal and previous to immersion in the cement. It is, moreover, possible to apply coatings which do not depend entirely upon oxygen absorption for their hardening and which contain ingredients of a fairly saturated

nature. Among these could be mentioned such coatings as are composed of resins dissolved in volatile solvents, as well as some special types of oil coatings which gave good results in Series I and II.

Relation between Film Porosity and Electrolysis.—The small current flow shown by certain of the specimens in the test may in part be attributed to their impervious character. Paints which form porous films allow the passage of water which may contain various electrolytes. Such films offer but small resistance to the

FIG. 12, Series 2.



passage of electrical currents. Paints which form highly impermeable films keep water away from the underlying iron and offer great resistance to the passage of electrical currents. Investigations which have determined the actual degree of porosity shown by various types of paint films have previously been made by A. M. Muckenfuss [4] and by the writer.[5] These tests have already afforded useful information to the designer of paints, and might

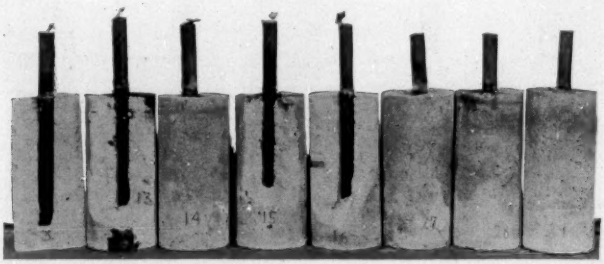
[4] "Report on a Permeability Test for Paints and Varnishes," A. M. Muckenfuss, *Proc. Amer. Soc. for Test. Mater.*, vol. xiv, Part 2, p. 361 (1914).

[5] "Excluding and Water-resisting Properties of Paint Films for the Protection of Iron and Steel," H. A. Gardner, Bull. 18, Scientific Section, Paint Mfrs.' Assn. of U. S., p. 17.

be studied with profit in the production of paints for the prevention of electrolytic corrosion.

Discussion of Bonding Tests.—Some paints gave good bonding tests, but failed to act as insulators. Among these may be mentioned Nos. 12, 19, and 20 (water paints) and Nos. 18 and 21 (lacquers). The latter two, composed of collodion and gutta-percha respectively, dried to a flat surface, which accounts for the good bond tests shown. Among the oil paints, No. 16, which also had the property of drying to a flat surface, gave a much better bond than paints of a similar composition which dried to a gloss surface. The good bonding tests shown by several of the water paints is readily explainable, the wet concrete exerting a

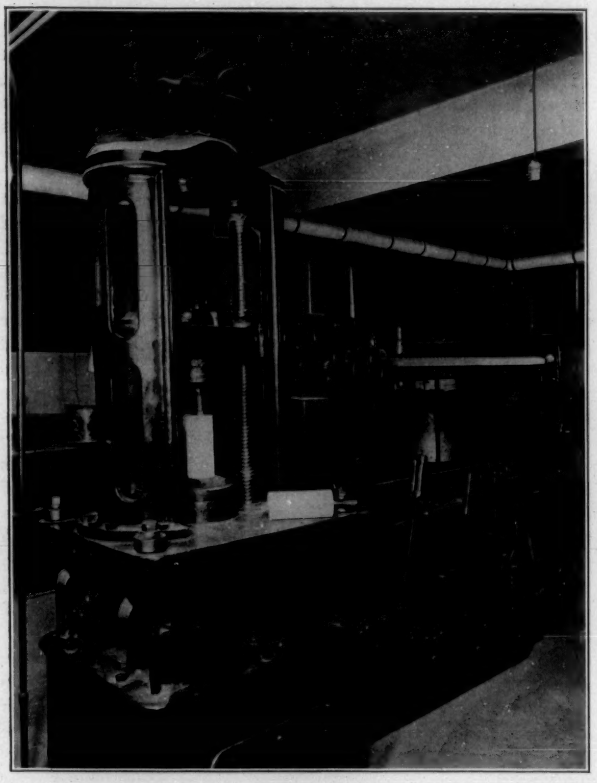
FIG. 13, Series 2.



solvent action upon such paints, which gave opportunity for direct contact with the steel. Some paints which gave excellent results in the insulating tests gave conversely poor results in the bonding tests. Among these may be mentioned Nos. 7 and 8, composed of sandarac and shellac respectively. Most of the oil-pigment paints made with raw linseed oil gave poor or only fair results. It is probable that the raw oil fails to dry hard, and, although apparently well dried, remains in a semi-oxidized condition. The oil films would in such cases be rather porous and therefore inefficient as insulators. Such films would be readily acted upon by the hydrogen evolved by electrolysis. Much better results were obtained with boiled linseed oil, a product that dries to a harder, less porous, and more fully saturated film. The value of the "sanded surface" method is shown by comparing test No. 27

with test No. 15, the paints used being of the same composition. The sanded surface of No. 27 gave much better insulating values

FIG. 14, Series 3.



and its bonding strength was double that of the unsanded specimen. Another instance of the value of the "sanded surface" method is shown by a comparison of specimens Nos. 28 and 14.

Use of Pigments.—It is quite likely that the nature of the pigment used in a paint designed to prevent electrolysis of embedded metal will have some bearing upon the results obtained from its use. The addition of a pigment to an oil usually increases the resistance to moisture and makes a more impermeable film. Theoretically, pigments which are of a non-conducting nature should be preferable. The inert pigments are examples of this type (asbestine, china clay, silica, etc.). There should, however, be present in a paint a sufficient quantity of rust-inhibitive pigment (basic pigments or pigments of the chromate type) to produce a passive condition of the steel, similar to the condition that is produced by the basic lime compounds in cement.

Prominent among the protective compounds that gave the best results are Nos. 2 and 9, composed of processed and heat-treated tung oil (Chinese wood oil). These compounds dried to a hard, non-porous film of a saturated nature. Had they been sanded, they undoubtedly would have given still better results. Distinction should also be accorded to Nos. 17, 27, and 28, although the good results obtained with the last two should be largely credited to the sanding of the surfaces during drying.

Arrangement of Results.—The protective compounds used in the tests have been divided into groups or types, and the composition of each is presented below. The formula numbers given correspond with the numbers of the test pieces containing rods to which such paints were applied. The same paints were used for the first and second series of corrosion tests, as well as for the bond tests. The tables also show the results obtained in each series of tests, and give the comparative bonding strength of each specimen. Charts I and II show the results of Series II and amperage hours. Figures 1 to 14 present the appearance of the various specimens tested.

Conclusions.—The corrosion of metal embedded in concrete structures, by stray currents of high voltage, is often productive of serious effects. The use of properly-made paints upon such metal constitutes a safeguard that should not be neglected by the engineer. Such paints may be prepared from the following substances.

The vehicle should contain:

Boiled or bodied oils or products which dry to a fairly saturated film.

Oils which dry by semi-polymerization rather than oxidation.

Oils which dry to a flat rather than a highly gloss surface.

The solid portion should contain a percentage of:

Pigments which are coarse and which therefore tend to form films having a rough surface.

Pigments which are inert and which do not act as conductors of electricity.

Pigments which are either basic or of the chromate type.

The painted metal should be "sanded" if possible.

The writer wishes to acknowledge the very valuable assistance throughout these tests of Mr. Leland P. Hart.

UNPAINTED BLANK SPECIMENS

Test specimen	Composition of paint	Results in Series I, 500-hour test	Results in Series II, 300-hour test	Series III, comparative bonding strength, pounds
23	Electrodes not painted.	Cracked at end of 240 hrs. Passed large amount of current throughout test. Anodes badly corroded and pitted.	Cracked at end of 96 hours. Passed large amount of current throughout test. Anodes badly corroded and pitted.	2010
24	Electrodes not painted.	Cracked at end of 50 hours. Same condition as No. 23.	Cracked at end of 96 hours. Same condition as No. 23.	2750

BITUMINOUS PAINT

1	Mixture of boiled, water-free coal-tar, lime, Portland cement, and rosin, thinned with benzol.	No cracking shown. Passed only small amount of current. Some excretion of tar paint at anode.	No cracking shown. Passed only small amount of current.	1530
17	Mixture of blown residual petroleum oil fluxed with gilsonite, dissolved in benzol and turpentine.	No cracking shown. Passed only small amount of current.	No cracking shown. Passed only small amount of current.	2810

OIL PAINTS

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
3	Red lead in oil. 30 pounds pigment to one gallon of raw linseed oil.	Did not crack, but large quantity of iron hydrate deposited at top surface of specimen, staining the concrete, showing weakened bond and corrosion.	Cracked at end of 192 hours. Considerable iron hydrate stain shown at surface of specimen throughout test. Iron quite badly corroded.	1370
13	Chrome green, 20 per cent. on 80 per cent. barytes base, ground in raw linseed oil (medium).	Cracked at end of 240 hours. Iron hydrate stain shown around anode at top surface of specimen early in test. Iron quite badly corroded.	Cracked at end of 192 hours. Same conditions observed as in Series I.	790
14	Blue lead in oil. 14 pounds pigment to one gallon raw linseed oil.	No cracking shown. Resistance to current was not marked. Slight corrosion observed. Deposit of iron hydrate at surface of cylinder.	No cracking shown. Same conditions observed as in Series I.	1250
15	Chromated iron oxide in oil. 12 pounds pigment to one gallon raw linseed oil.	No cracking shown. Only slight corrosion observed.	Cracked at end of 144 hours. Deposit of iron oxide at top of cylinder.	930
16	Blue lead ground in heavy-bodied linseed oil reduced with an equal quantity of turpentine to cause paint to dry to a flat surface. Formed a thin film.	Small crack developed at end of 240 hours. No surface deposit shown, indicating good bond. Anode showed considerable corrosion.	Small crack developed at end of 216 hours. Same condition as in Series I.	1400
27	Chromated iron oxide in treated tung oil. 12 pounds pigment to 1 gallon raw linseed oil. "Sanded surface."	Not in Series I.	No cracking shown. Passed only small amount of current. No deposit on surface. Excellent condition.	2000

OIL PAINTS—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
28	Mixture of equal parts of No. 14 and No. 16. "Sanded surface."	Not in Series I.	No cracking shown.	1880
29	Asbestine pigment ground in No. 9 oil. "Sanded surface."	Not in Series I.	No cracking shown. Passed only very small amount of current. Passed slightly more current than No. 9. In excellent condition throughout test.	Not in Series III.

AQUEOUS PAINTS

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
4	Silicate of soda (40° Be.).	Cracked at end of 240 hours. Very little resistance to current.	Cracked at end of 168 hours. Very little resistance to current. Examination of iron showed some clear areas and some pitted.	700
10	Liquid glue.	Cracked at end of 240 hrs. Passed large amount of current throughout test. Considerable iron hydrate at top of specimen and permeated throughout. Concrete around anode.	Cracked at end of 96 hours. Passed large amount of current. Dense deposit of iron hydrate at top of test piece. Bad corrosion of metal shown.	100
11	Silicate of soda, 20° Be., and graphite ground together, equal parts by weight.	Cracked at end of 144 hrs. Passed considerable current. Corrosion marked.	Cracked at end of 96 hours. Passed large amount of current. Corrosion marked.	Specimen faulty.

AQUEOUS PAINTS—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
12	Silicate of soda, 20° Be., and iron oxide pigment ground together, equal parts by weight.	Cracked at end of 240 hrs. Passed considerable current.	Cracked at end of 192 hrs. Passed considerable current.	1870
19	5 per cent. aqueous solution of sodium resinate.	Cracked at end of 240 hrs. Passed more current than one blank specimen.	Cracked at end of 144 hrs. Passed considerable current.	1890
20	5 per cent. aqueous solution of sodium resinate ground with an equal weight of iron oxide.	Cracked at end of 240 hrs. Passed large amount of current.	Cracked at end of 196 hrs. Passed large amount of current.	2580

LACQUERS

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
7	Gum sandarac in alcohol, 32 ounces solution.	No cracking shown. Only small amount of current passed. No stain at surface.	Only small amount of current passed. No stain at surface.	990
8	Gum shellac in alcohol, 32 ounces solution.	No cracking shown. Passed more current than No. 7. No stain.	Passed more current than No. 7. Slight stain at surface.	490
18	Soluble nitrated cotton dissolved in amyl and ethyl acetate, 8 ounces solution.	Cracked at end of 240 hours. Large amount of current passed. Some stain at surface.	Cracked at end of 192 hrs. Large amount of current passed. Iron hydrate stain at surface.	2480
21	Gutta-percha dissolved in benzol, 3 ounces solution.	Cracked at end of 240 hrs. Passed considerable current. Stain at surface.	Cracked at end of 96 hours. Passed considerable current. Considerable stain at surface.	2600

LACQUERS—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
26	Condensation product of phenol and formaldehyde dissolved in alcohol.	Not in Series I.	No cracking shown. Passed only small amount of current. Some iron stain at surface and a small deposit of dark cherry stain, due to product of reaction between the phenolic bodies and the lime in the cement.	1380

OILS AND VARNISHES

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
2	Special heat-treated tung oil compound thinned with turpentine.	No cracking shown. Concrete test specimen was of faulty construction, a portion of the cathode being exposed. Nevertheless the specimen passed but very small amount of current. Film was tough and elastic.	No cracking shown. Only moderate amount of current passed. No stain.	2665
5	Double-boiled linseed oil (lead and manganese drier).	Cracked at end of 140 hours. Passed considerable current throughout test. Heavy deposit of iron stain at surface.	Only a very fine crack developed at end of test. Passed considerable current throughout test. No stain.	1680

OILS AND VARNISHES—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
6	Kauri gum-linseed oil varnish.	Only slight crack shown. Small amount of current passed. No stain.	No cracking shown. No stain.	1790
9	Processed tung oil compound.	No cracking shown. Passed only a very small amount of current. Gave excellent insulation value. No stain.	No cracking shown. Passed only a very small amount of current. Had a high electrical resistance. No stain.	1990
22	Mixture of equal parts of No. 9 and No. 21.	No cracking shown. Passed less current than No. 21, but more than No. 9. No stain.	No cracking. Passed less current than No. 21, but more than No. 9. No stain.	Specimen faulty.

Two New Modifications of Phosphorus. P. W. BRIDGMAN. (*Amer. Chem. Soc. Journ.*, xxxvi, 1344.)—Under the influence of high pressure, ordinary white phosphorus is transformed into a new modification. The transition temperature is a linear function of the pressure and varies from about – 80° C. at the atmospheric pressure to + 64.4° C. at 12,000 kg. per square centimetre. This modification was obtained in microscopic crystals, probably in the hexagonal system. A black modification has also been obtained by subjecting the ordinary white form to a temperature of 200° C. and a pressure of 12,000 kg. per square centimetre. This variety, the formation of which is irreversible, has the high density 2.691 at the ordinary temperature, and possesses moderately high electrical and thermal conductivity. Its specific heat between 30° C. and 100° C. is 0.170, which is decidedly lower than the corresponding value for red phosphorus, the latter being apparently less stable than the black form.

Protecting Garment for Aviators. ANON. (*Sci. Amer.*, cxi, No. 12, 223.)—Richard Kockrow, of Nieder, Lausitz, Germany, has secured a patent, No. 1,104,808, for an aviator's protecting garment, formed of layers of felt and aluminum, spring-spaced apart to protect the wearer from the shock in case of a fall.

METHODS, DATA, AND NEW APPARATUS FOR MEASURING ELECTRICAL CONDUCTIVITY ABOVE 1500° C. OF VAPORS AT NORMAL PRESSURE.*

BY

EDWIN F. NORTHRUP, Ph.D.,

Palmer Physical Laboratory, Princeton University.
Member of the Institute.

It is certain that when the temperature exceeds 1200° C. many substances, ordinarily called insulators, conduct electricity fairly well. It is probable that near and above this temperature every known material, whether in the solid, liquid, or vapor condition, is a fair conductor of electricity. By this statement I mean that a pressure of less than 100 volts will send enough current through a section of a square centimetre and a few millimetres of length of the material to be readily measured with an instrument reading in milliampères. With further elevation of temperature, to the neighborhood of 1600° C., the so-called refractories, ordinary gases, and some, at least, of the metallic vapors, acquire a conductivity which is readily measured with the ordinary deflection instruments: a voltmeter and a milliampèremeter. The conduction here referred to is not arc conduction, and the current which flows steadily increases with application of voltage from zero voltage to a voltage less than 100 volts, ordinarily. The ratio of the voltage to the current is not, however, constant and obeys no simple law.

While the general fact has long been known that very hot gases and vapors are more or less conducting at high temperatures and at atmospheric pressure, so far as my reading informs me, the facts and laws of the conduction have received little study and few quantitative measurements have been made. The subject has appeared to me to have both practical and theoretical value, and I have begun an extended investigation along this line, and what follows is a brief report of the beginnings made.

* Read by title at the meeting of Section D, A. A. A. S., December 31, 1914, and communicated by the Author.

Gas and vapor conduction investigations have been heretofore confined chiefly to experiments carried on at ordinary temperature and low pressure. The gases or vapors investigated under these conditions would, if liquefied, be classed as insulators. If, however, we investigate the conductivity of a metallic vapor, we study the conductance of a substance which if liquefied becomes an excellent metallic conductor. The greater number of the metals, however, do not exist as vapors except at very elevated temperatures, and hence, to investigate the nature of the conduction of vapors which if liquefied become good conductors, we must work at very high temperature. If we can combine high pressure with high temperature we shall have at our disposal a searching experimental method of ascertaining the true nature of metallic conduction.

The investigation requires:

(*a*) Suitable apparatus for controlling and bringing the temperature of a confined space from 1400° C. to 1800° C. (2552° F. to 3272° F.);

(*b*) A rapid and certain means of measuring the high temperature employed;

(*c*) Suitable containers for the metallic vapors under study;

(*d*) Suitable apparatus for maintaining the hot vapors under high pressure.

Some progress has been made in all these developments except the last, which has not yet been attempted.

Preliminary experiments showed that the character of the conduction depends:

1. Upon the form of the container;
2. Probably upon the material of the container;
3. Upon the applied voltage;
4. Upon the direction of the applied voltage;
5. Upon the temperature;
6. Upon the frequency when an alternating voltage is employed;
7. Upon the nature of the gas or vapor.

It soon became apparent that, in order to discover, measure, and interpret the phenomena, the measurements should be made with unidirectional e.m.f. which could be commutated, and then be repeated with an alternating e.m.f. of different known frequencies.

When a unidirectional e.m.f. is employed the measuring appa-

ratus may consist of a d.-c. voltmeter, reading to 150 volts, and d.-c. milliampèremeters with scales arranged to read from 10 to 1500 milliampères at the top of the scale. When an alternating e.m.f. is employed I have used an electrodynamometer of the Rowland type in conjunction with a Wheatstone bridge. An a.-c. milliameter and a.-c. voltmeter could and should be used to check and help to interpret the results gotten with a Wheatstone bridge.

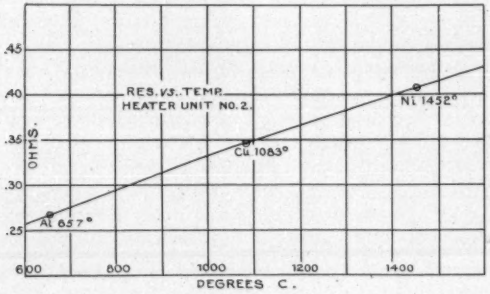
The piece of apparatus which required the greatest amount of thought and experimentation for satisfactory construction was the electric furnace. The experience which had been acquired in developing a large-model, high-temperature graphite furnace, which gives readily 1600° C. (2912° F.), enabled the furnace problem to be solved in an entirely satisfactory way. It was found, after making several life tests, that a graphite heater-unit, while entirely satisfactory for a large furnace, is less so for a small furnace, and an interchangeable heater-unit which employs a very high melting-point metal as a resister material was devised, which fits into the same space in exactly the same kind of a furnace case as had been previously constructed for a small-model graphite furnace. Another reason for employing a metal for a resister element lies in the fact that, when the furnace is heated slowly, the furnace resistance, which may be obtained by reading volts and ampères or volts and watts, bears a definite relation to the temperature of the furnace. The curve relating temperature and resistance is obtained by heating the furnace very slowly and noting its resistance at the moment at which small wires of different metals, whose melting-points are known, melt. For this purpose I use the wires, aluminum, copper, and nickel. When more precision is required in the measurement of temperature, a thermocouple or tin pyrometer, or an optical pyrometer may be used.

Fig. 1 is a curve relating resistance and temperature of one of the heater-units belonging to the furnace used in my measurements.

This type of furnace has a chamber of cylindrical form 2.2 Cm. in diameter and a heating length of about 13 Cm. The metal resister material is protected from oxidation by the CO + N gases which the furnace automatically develops as soon as a red heat is reached. The furnace may be safely heated to a temperature which will melt platinum. In a test made

on one of the units the furnace was heated and cooled ten times. In two of the heatings the temperature was raised to over the melting-point of platinum. After this the current was kept on continually until the unit gave out. The unit lasted a total of 137½ hours, the temperature seldom going below 1400° C. and most of the time being above the melting-point of nickel. Some minor changes have been made, suggested by the results of this test, which will still further increase the life of the heater-units. The watt input required to give an equilibrium temperature above the melting-point of nickel was about 1030 watts. When it is desired to heat the furnace rapidly from room temperature to 1500° C. an input of about 1600 watts is used. In one test an

FIG. 1.



input of 1660 watts brought the furnace to an equilibrium temperature of 1645° C. in about 2½ hours. When at this temperature the furnace called for 28.6 volts and 58 ampères.

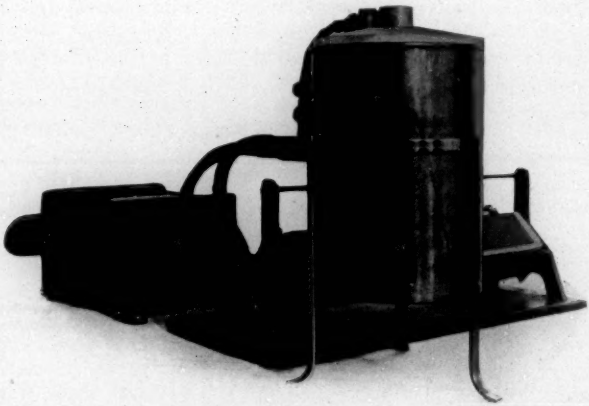
Fig. 2 is a reproduction of a photograph of the furnace, transformer, and carbon rheostat, which together make up the furnace outfit. The replaceable unit is shown in Fig. 3.

An exhausted unit is very readily replaced by a new one, when the full life of the furnace becomes restored.

To hold the heated vapor to be measured a container of Acheson graphite was devised. This is illustrated in Fig. 4. It consists of a crucible of cylindrical form which fits the furnace chamber. A hollow cylinder of graphite 8 mm. in external diameter is located on the axis of this crucible. It is held in position and insulated

from the crucible by a piece of baked lavite, which also forms a cover for the furnace chamber. The resistance measured is that of the hot gas or vapor in the space between the outer surface of the inner cylinder and the inner surface of the cylindrical crucible. The internal diameter of the crucible is 1.75 Cm. The construction and dimensions are made clear in the figure. With this construction the temperature to which the vapor may be raised is limited by the melting temperature of lavite, which is in the neighborhood of 1525° C. A better material will be sought and selected for future work.

FIG. 2.



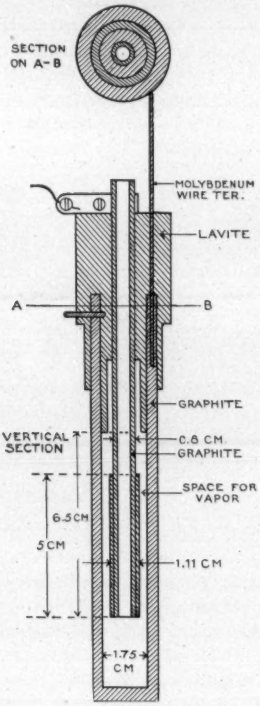
A small piece of metal, of which the vapor resistance is to be determined, is placed in the bottom of the graphite crucible and the temperature of the furnace is steadily increased (never being allowed to decrease while the measurement is in progress), and it is assumed that the metal in vaporizing expels all the CO + N gases which are formed within the crucible as soon as a red heat is attained.

It is recognized that when the pressure is atmospheric the quantity of metal which remains in the crucible after the original supply has all been vaporized is very minute, and that quantitative measurements, respecting the ratios of the conductivities of the

vapors of different metals, will not have much meaning until means are provided for maintaining the metallic vapors under pressure. Furthermore, it is quite evident that when the temperature exceeds 1200° C. the interior of the graphite crucible is filled

FIG. 3.

FIG. 4



with minute particles of carbon intermingled with the metallic vapor, or CO + N gases when no metal is present. These minute particles of carbon may, and probably do, have a large part in the electrical conduction observed. A far better material out of which to construct a container would be a tube of pure metallic tungsten.

The cost of this, however, has, for the time being, precluded its use. I do not consider, therefore, that the measurements so far made have any value in giving information respecting the relative conductivity of pure, uncontaminated metallic vapors. Nevertheless, the results obtained are satisfactorily accurate for a pure CO + N atmosphere filled with minute particles of carbon, and they reveal the general characteristics of the phenomena exhibited, which in some respects, to be pointed out, are extremely interesting.

Summarizing in respect to the apparatus, it may be said that the methods of producing and measuring the temperature are entirely satisfactory, and that the kinds of measurements which should be made for the discovery and interpretation of the phenomena have been quite clearly defined; but much work must be done in the design and construction of a suitable container and in means for maintaining the vapors under high pressure. The measurements thus far made must be considered as mere skirmish measurements, so to speak, made to discover the general character and drift of the phenomena.

The Measurements.

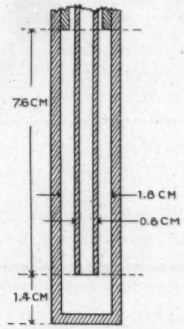
If no metal is present in the graphite crucible, it may be assumed that when the temperature is above a red heat the oxygen of the air unites with the graphite to form CO, and that the atmosphere in the crucible is a mixture of carbon monoxide and nitrogen. If the temperature is raised to the neighborhood of 1500° C. there is added to this gas-mixture a certain quantity of very finely divided and chemically uncombined carbon. There are several lines of evidence that minutely divided carbon is present in the uncombined state. For example, refractory ware like marquardt porcelain placed in the crucible becomes very much blackened. The first measurements were planned to observe the characteristics of the electrical conduction of this gas.

Measurements of resistance were made using direct e.m.f., making the central cylinder alternately positive and negative, and also with alternating e.m.f. of 60 and 38 cycles. The several measurements I have made with alternating currents are, however, complicated and difficult to interpret and will not be included in this report.

Since it was thought that it might be desirable to reduce the

resistance readings to specific values, the resistance was obtained of one of the containers, constructed with the same dimensions as were used in some of the gas-resistance measurements (see Fig. 4) when this was filled with a saturated solution of NaCl, having the known resistance of 4.425 ohms at 20° C. between opposite faces of a centimetre-cube of the solution. In obtaining this constant, contact resistance errors were largely avoided by first filling the container with mercury, the measured resistance in this case being due almost wholly to contact resistance. The result gave the net resistance of the container filled with saturated NaCl solution at 20° C. as about 0.2 ohm. The results ob-

FIG. 5.



tained, using a fall of potential method and direct e.m.f.s, are given below. The diagrams and curves, with explanatory notes, which are here given, make clear the procedure and results without further description.

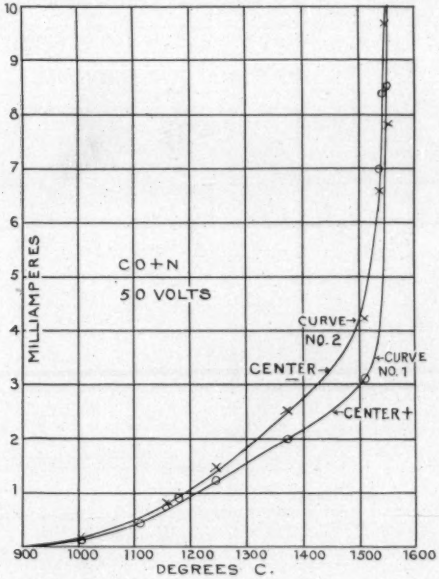
Volt-ampère Curve of CO + N. Measurement No. I.

The central cylinder of the container was given the same diameter throughout its length. The dimensions used in the measurements recorded in curves 1 and 2, Fig. 6, and 3 and 4, Fig. 7, are given in the cross-sectional diagram, Fig. 5. The connections employed are given in Fig. 8.

The procedure was as follows: The temperature of the furnace was raised very slowly; the furnace temperature was ascer-

tained by reading the volts at the furnace terminals and the watts on the primary side of the transformer. The furnace resistance was calculated from the data, and the temperature was then taken from an experimentally gotten curve, previously obtained with much care. The e.m.f. at the electrodes of the container was maintained by means of the rheostat (Fig. 8) at exactly 50 volts.

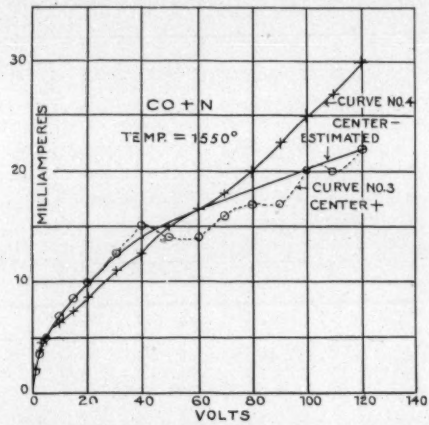
FIG. 6.



Readings of milliampères were made at frequent intervals, as the temperature slowly rose, alternate readings being taken, first with the center electrode made positive and then with this electrode negative. When the temperature had reached 1550° C. the furnace input was adjusted so that, as closely as possible, this temperature was maintained. Then, as quickly as possible, readings of milliampères were taken as the voltage was varied from 0 to 120

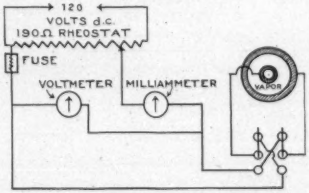
volts. The readings were taken with center electrode alternately positive and negative. The voltage was varied in steps of 1 volt from 0 to 5 volts, in steps of 5 volts from 5 to 20 volts, in steps of 10 volts from 20 to 120 volts.

FIG. 7.



The results obtained are plotted in two sets of curves, the first (Nos. 1 and 2, Fig. 6) relating milliampères and degrees centigrade, the voltage being kept constant at 50 volts, the second

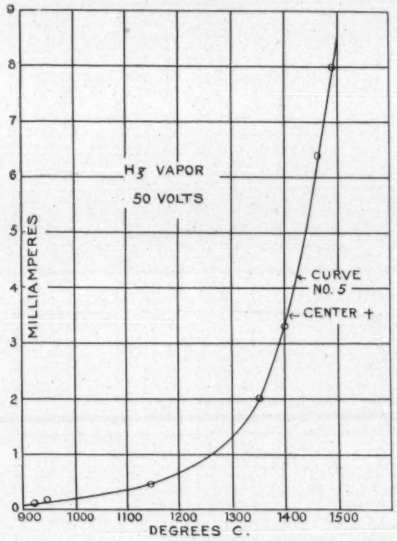
FIG. 8.



(Nos. 3 and 4, Fig. 7) relating milliampères and volts, the temperature being maintained constant at approximately 1550° C. After the furnace had cooled the container was examined and the lower end of the lavite top piece was found to show evidence of

fusion. It is probable, therefore, that some vapors emanating from the lavite had contaminated the CO + N atmosphere at the highest temperatures. This may influence somewhat the absolute values obtained, but hardly, it is thought, the general shape of the curves Nos. 3 and 4, and not at all the shape of or absolute value of

FIG. 9.



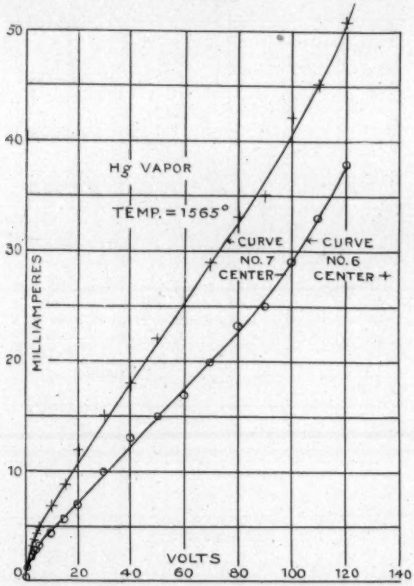
the curves Nos. 1 and 2 under the temperature of 1525° C., which is given by the Bureau of Standards as the fusion temperature of lavite.

Volt-ampère Curve of Mercury Vapor. Measurement No. II.

Without any modification in the apparatus or method, curves were obtained when the crucible container was filled with the vapor of mercury. Before the furnace was heated a few grammes of mercury were placed in the container. To avoid a reëntrance of air into the container after the mercury had all become vaporized, a quartz tube was sealed into the top of the central graphite

electrode. To the end of this a rubber tube was attached and bent into an S to form a trap for the mercury which distilled over. So long as the temperature of the furnace was rising or stationary it was assumed that no air could reënter the container. The curves (Nos. 5, 6, and 7) obtained in this case are given in Figs.

FIG. 10.



9 and 10. They have the same general character and magnitude as the curves for CO + N, but are more regular in form.

Measurement of the Asymmetric Resistance of Hot Gas. Measurement No. III.

It is quite apparent, from an examination of the data and curves, that the current passes, even between two electrodes of the same material but of different dimensions, more easily in one direction than in the other, and that the asymmetry changes sign with

FIG. 11.

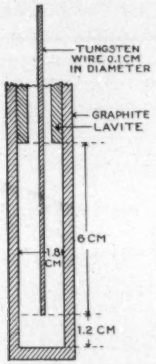
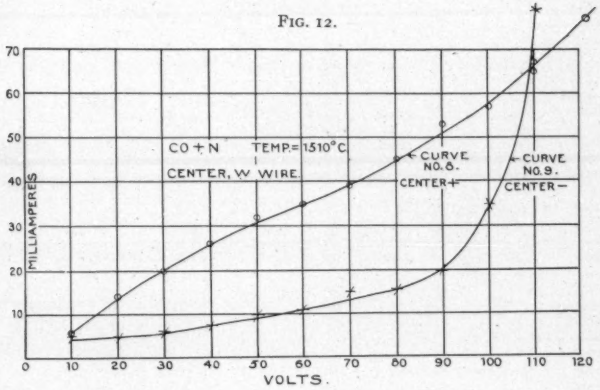


FIG. 12.



increase of voltage. To investigate this phenomenon further another set of measurements was taken with CO + N gases and the container fitted with a central electrode made of a tungsten wire 1 mm. in diameter. Fig. 11 gives a cross-sectional view with dimensions of the modified form of container used.

The temperature was successfully maintained constant during

all the time that the readings were being taken, at 1510° C. The volts at the electrodes of the container were varied from 0 to 119 volts, and the corresponding milliampères were read as the central electrode of tungsten was made alternately positive and negative.

The data, as taken directly from note-book, and the plot of these data are given below in a table and in Fig. 12, curves 8 and 9.

December 23, 1914. Observers—E. F. Northrup and Mrs. E. F. Northrup.

Note.—Furnace heated until nickel melted (1452° C.). Temperature allowed to become steady at 1510° C. during measurement.

Volts at furnace terminals = 29.68, 29.8, 29.8.

Watts input = 1940, 1950, 1952.

Calculated furnace resistance at 1452° C. = 0.455_3 ohm.

Pol'ty of W. Ter.	Applied volts	Milli-ampères	Furnace kilowatts	Furnace volts	Estimated furnace temperature	Notes
			1.98	30.4	1510°	+ means current passes from tungsten to wall of cylinder through gas, and − means in reverse direction.
+	10	6	....	....	1510°	
−	10	5	....	....	1510°	
+	20	14	....	....	1510°	
−	20	5	1.96	30.4	1510°	
+	30	20	....	....	1510°	
−	30	6	....	....	1510°	
+	40	26	1.96	30.4	1510°	
−	40	7.5	....	....	1510°	
+	50	32	....	....	1510°	
−	50	10	1.94	30.2	1510°	$\rho = \frac{2.73RL}{\log_{10}\frac{b}{a}} = 13000 \frac{\text{volts}}{\text{milliamp.}}$
+	60	35	....	....	1510°	
−	60	11	....	....	1510°	
+	70	39	1.96	30.2	1510°	$\rho = 23320$ ohms.
−	70	15	....	....	1510°	
+	80	45	....	....	1510°	
−	80	15.1	1.94	30.2	1510°	
+	90	53	1.94	30.4	1510°	Very steady, accurate point.
−	90	20	....	....	1510°	
+	100	57	....	....	1510°	
−	100	35	1.94	30.3	1510°	With long application of voltage reading slowly increased to 45 milliampères.
+	110	65	....	....	1510°	
−	110	75	....	....	1510°	
+	110	67	....	....	1510°	
+	119	75	1.92	30.2	1510°	Extra reading.

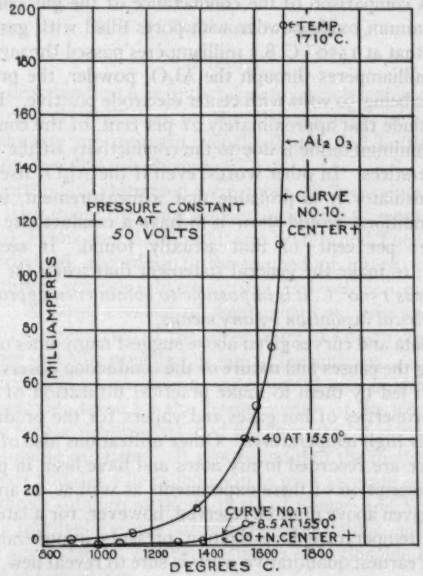
Note.—Above data plotted in curves Nos. 8 and 9.

Current vs. Temperature Curve of Pure Aluminum Oxide. Measurement No. IV.

The comparatively large current which, under a pressure of 50 volts, will pass through a mixture of hot CO + N gas, as shown

by measurement No. 1, suggests the thought that the electrical conductivity found for all oxide powders and refractory materials at high temperatures may be due, in considerable measure, to the conductivity of the hot gases which permeate the solid material. Thus, if the space between the electrodes of an electrolytic cell were filled with wet sand, measurement would show a low resistance between the electrodes. One would not, however, conclude,

FIG. 13.



from a measurement of the conductance between the electrodes, that the observed conductance is due to a conductivity of sand. Similarly, if all hot vapors and gases conduct, and all refractory materials are porous at high temperature, one cannot conclude that the conductivity of a refractory measured while immersed in a hot gas is only due to the conducting property of the material itself. To test this mater quantitatively a container of the same

form and dimensions as was employed in measurements Nos. I and II (see Fig. 5) was packed full of very pure, chemically-prepared Al_2O_3. Milliampères *vs.* degrees centigrade were measured, the pressure being 50 volts, and the center electrode maintained positive. The results obtained are given in curve No. 10, Fig. 13. The curve No. 1, Fig. 6, obtained with CO + N only in the container, taken under identically similar conditions, is replotted to the same scale in Fig. 13 (and is called curve No. 11) to give directly a comparison of the conductance of the gas only and of pure aluminum oxide powder with pores filled with gas. It will be noted that at 1550° C. 8.5 milliampères passed through the gas and 40 milliampères through the Al_2O_3 powder, the pressure in both cases being 50 volts with center electrode positive. Hence we may conclude that approximately 21 per cent. of the conductivity of the aluminum oxide is due to the conductivity of the hot gases in its interstices. In other words, even if the Al_2O_3 itself were a perfect insulator it is probable that a measurement, under the above conditions, would show it to have a conductivity approximately 21 per cent. of that actually found. It seems safe, therefore, to make the general statement that *when the temperature exceeds 1500° C. it is impossible to obtain even approximately good electrical insulation by any means.*

The data and curves given above suggest many lines of inquiry respecting the causes and nature of the conduction observed, and I have been led by them to make practical utilization of the conducting properties of hot gases and vapors for the production of excessively high temperatures. Other utilizations also of seeming importance are recorded in my notes and have been in part tried out. A description of these experiments as well as an analysis of the data given above must be reserved, however, for a later report.

High temperature investigation presents innumerable problems, and earnest quantitative work is sure to reveal new, interesting, and, very probably, commercially important results. It is, in my judgment, the most fruitful field for chemical and physical inquiry which is at this time presented to chemists and physicists.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF SOME RECENT METHODS FOR THE DETERMINATION OF TOTAL SULPHUR IN RUBBER.

By J. B. Tuttle and A. Isaacs.

[ABSTRACT.]

THIS investigation was undertaken to learn whether or not the methods recently published for the determination of sulphur in rubber were any improvement over the Waters and Tuttle method, the one now in use at this Bureau.

The methods investigated were those of Spence and Young; Deussen, Alexander, the Joint Rubber Insulation Committee, Kaye and Sharp; Frank and Marckwald, and Waters and Tuttle. These were subdivided, according to the method of attack, into three classes: direct solution, direct fusion, and solution and fusion methods. A large number of determinations were made on a number of samples, two of the latter being of known composition which were specially prepared by one of the authors.

The methods which have been compared may be divided into two classes, viz., those for the determination of the total sulphur and those for the determination of sulphur other than that present in the insoluble sulphates. It was found that the methods of the second class could not be relied upon to give accurate results.

The direct solution methods, those of Spence and Young, and Deussen, involve the use of concentrated nitric acid. This was first suggested by Henriques, but is objectionable because it gives rise to low results.

The direct fusion methods, those of Alexander, the Joint Rubber Insulation Committee, and Kaye and Sharp, are reliable only when the free sulphur content is low, and are therefore not applicable to routine analysis.

The solution and fusion method of Frank and Marckwald was found to be unreliable when the free sulphur was high. The

* Communicated by the Bureau.

Waters and Tuttle method was found to give satisfactory results and recommended for general use.

A new suggestion is offered, namely, to determine separately the free sulphur and the sulphur remaining after the extraction, reporting the sum of the two quantities as the total sulphur. This procedure eliminates the troublesome effect of the free sulphur upon the determination of the total sulphur.

INVESTIGATION OF THE DURABILITY OF CEMENT DRAIN TILE IN ALKALI SOILS.*

[ABSTRACT.]

THE durability of cement mortar and concrete when exposed to concentrated alkali salts in soil and water has been questioned by many engineers and users of concrete. In the Western States many irrigation and other structures have been built of concrete in alkali soils, and cases of partial or complete failures of some of these structures have been attributed to the effect of alkali salts.

Laboratory investigations have shown that cement concrete is subject to disintegration by alkali salts under certain conditions, but practical experience has shown that some concretes are much less susceptible to the action of the salts than others and are quite permanent, even if exposed in very concentrated alkali soils. It was intended, in outlining this investigation, to make it an actual field test of practical, full-sized specimens composed of concrete of known composition, so that all conditions might be similar to those in which structures are exposed in the field.

In 1913 a committee, consisting of a representative from the United States Reclamation Service, the Drainage Division of the Department of Agriculture, the Association of American Portland Cement Manufacturers, and the Bureau of Standards, outlined a programme of tests to determine the effect of alkali on cement mortars of a known commercial quality. Since several millions of dollars are being spent annually in the drainage of alkali soils in the western part of the United States, and because of its economic

* By R. J. Wig and G. M. Williams in coöperation with S. H. McCrory, Drainage Division, Department of Agriculture, and L. R. Ferguson, Association of American Portland Cement Manufacturers, and E. C. Bebb, U. S. Reclamation Service.

importance, it was considered advisable to make observations on cement drain tile of known composition which would be exposed under normal service conditions in operating drains in concentrated alkali soils.

Over eight thousand cement drain tile, 12 inches long and 8 inches inside diameter, were manufactured in a commercial tile factory in Iowa during August and September, 1913. They included 16 different types, made up of mixtures from the leanest to the richest commercially practicable. Records were kept of all steps in the process of manufacture. Care was taken to produce a uniform and good quality of product, but no methods or materials were introduced which could not be reproduced in any well-equipped cement tile factory.

After all tile had cured for a period of at least one month shipments of a carload were made to projects in each of the following States: Colorado, Wyoming, Montana, Washington, Arizona, New Mexico, Utah, Minnesota, and Missouri.

The tile were installed in the first seven States in soils which contain large quantities of alkali salts and where concrete structures were thought to have been damaged by alkali action. The tile in Minnesota and Missouri were placed where they would be exposed only to fresh water, and a separate shipment was made to Ames, Iowa, where the tile were stored in the open above ground and exposed to the weather.

Installation was completed in November, 1913, and the tile were so arranged that sections at each project containing two tile of each series can be removed for test annually without disturbing the remainder of the line. Ten such sections were placed end to end at each project. Samples of soil, water, and alkali salts, where available, were secured for analysis.

The first year's tests were made in the fall of 1914. One section at each project, containing 32 tile, two of each series, was removed and tested at the site in a portable tile testing machine especially designed for the purpose. Samples of tested tile, as well as soil and water samples, were secured for chemical analysis. The tile removed for test were replaced with two other series of cement tile which were made for this purpose, and of which complete records of materials and methods were recorded. It is also planned to replace those tile removed for test during 1915 with additional cement tile manufactured by different methods.

CONCLUSION.

The details of this investigation and the results of the first year's tests are published at this time because of its economic value in demonstrating to those who are now using or considering using cement drain tile that special care should be observed to employ only the best materials and good workmanship in its fabrication, and if these precautions are not observed failure will result if the drain is located in some of the more concentrated alkali soils similar to those found at Grand Junction, Col., and Garland, Wyo.

Drain tile manufactured in a manner as herein described for series 2, 9, 10, 11, 13, and 15, of cement mixtures not leaner than one part cement to three parts of aggregate, are apparently unaffected structurally when exposed for one year in operating drains in very concentrated alkali soils, similar to any of those included in this investigation.

Drain tile made from cement mixtures leaner than one part cement to three parts of aggregate should not be used in localities where the character of the alkali and concentration is similar to that found at the site of the experimental drains at Grand Junction, Col.; Montrose, Col., and Garland, Wyo.

Drain tile manufactured in the manner herein described of one part cement to four parts of aggregrate, the leanest mixture used, is apparently unaffected structurally by exposure for one year in an operating drain in concentrated alkali soils similar to those found at Fort Shaw, Mont.; Sunnyside, Wash.; Yuma, Ariz., and Roswell, N. M.

Other than the above, no very general conclusions should be drawn from this investigation until the results of further tests are obtained. It is anticipated that this report will be amended from time to time as the results are available.

The Bureau would be pleased to receive information concerning the behavior of concrete exposed to concentrated alkali soil which may come to the attention of engineers or others interested in the use of concrete under these conditions.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, February 17, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 17, 1915.

DR. GEORGE A. HOADLEY, *Temporary Chairman.*

Additions to membership since last report, 9.

Mr. George H. Clamer, chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

The standing committees for the year 1914–15 were announced.

Dr. Francis D. Patterson, Director, Department of Sanitation and Accident Prevention, Harrison Brothers & Company, Inc., J. G. Brill Company, and the Electric Storage Battery Company of Philadelphia, presented an interesting communication on "Sanitation and Accident Prevention in Industry."

The campaign of education in accident prevention among the general public as well as among workmen was fully set forth and its importance upon the welfare of the community at large was pointed out. Attention was called to the necessity for guarding against accidents in the home, the workshop, and in public places, and the numerous devices now in use for the protection of workmen and others were described.

The importance of sanitation in factories with special relation to the prevention of occupational diseases was also given full consideration. The speaker illustrated the subject by numerous lantern slides and moving pictures.

After a rising vote of thanks the meeting adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1915.

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

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R. S. Perry,
George D. Rosengarten.

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MEETINGS.

Gellert Alleman,
G. S. Barrows,
G. H. Clamer,
George R. Henderson,
H. A. Hornor,
Herbert E. Ives,
M. M. Price,
James S. Rogers,
George D. Rosengarten,
Coleman Sellers, Jr.

MUSEUMS.

Henry F. Colvin,
Charles Day,
James M. Dodge,
Richard Gilpin,
George A. Hoadley,
Harry F. Keller,
Wilfred Lewis,
A. E. Outerbridge, Jr.,
Wm. H. Thorne,
Wm. J. Williams.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 3, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 3, 1915.

MR. GEORGE R. HENDERSON *in the Chair.*

Mr. G. H. Clamer was unanimously elected Chairman for the year 1915.
The following report was presented for first reading:

No. 2586.—Dobbins's Daylight Rods.

The following reports were presented for final action:

No. 2614.—Hardinge Conical Ball and Pebble Mill. John Scott Legacy Medal and Premium recommendation to H. W. Hardinge adopted.

No. 3621.—Wahl Adding Machine. John Scott Legacy Medal and Premium recommendation to H. E. Goldberg and J. C. Wahl and Edward Longstreth Medal to Wahl Adding Machine Company adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, January 28, 1915, at 8 o'clock P.M., with Dr. Henry H. Donaldson in the chair. The minutes of the previous meeting were read and approved.

Dr. Donaldson introduced Ulric Dahlgren, Ph.D., Professor of Biology in Princeton University, who delivered a lecture on "The Production of Light by Animals." The wide distribution of light-producing organisms was demonstrated, and typical forms from the bacteria and fungi, and from several of the larger groups of the animal kingdom, were described. The anatomy and histology of the light-producing organs, including their reflectors, lenses, focusing devices, diaphragms, protective mantles, and colored screens, were discussed, as were the uses of the light for mating, protective and warning signals, and for illumination and ornamentation. The chemistry, physics, and physiology of the light production received attention, and an explanation was given of the different methods of oxygen supply and of internal and external combustion. The address concluded with remarks on the possibility of better light production by man. The lecture was illustrated by means of lantern slides and of luminescent bacteria and worms. After discussion of the paper the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, February 4, 1915, at 8 o'clock

P.M., with Dr. Joseph P. Remington in the chair. The minutes of the previous meeting were read and approved.

Carl L. Alsberg, A.M., M.D., Chief of the Bureau of Chemistry of the U. S. Department of Agriculture, delivered an address on "Moisture in Agricultural Products." The quantity of moisture present in plant and animal tissues was discussed. The relation of the moisture content to the usefulness of a foodstuff, and its influence on spoilage were pointed out, as were certain other economic relationships, including the changes in water content during transportation and storage. An account was given of the relation of the moisture content of agricultural products to various industries.

The paper was discussed by Drs. Pennington, Remington, Keller, Miller, Pearson, Alsberg, and Mr. Bower. A vote of thanks was extended to Dr. Alsberg and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A joint meeting of the Section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, February 11, 1915, at 8 o'clock.

Mr. W. C. L. Eglin and Mr. H. V. Sanville presided jointly.

The minutes of the previous meeting were approved as published.

E. B. Rosa, Ph.D., Chief Physicist, Bureau of Standards, Washington, D. C., delivered an interesting and instructive lecture, entitled "Recent Researches in Electricity at the Bureau of Standards." In this lecture Dr. Rosa outlined the general plan of the buildings occupied by the Bureau of Standards, and then described particularly the arrangement and equipment of the Physics Building. With the aid of lantern slides he described recent work done at the Bureau in connection with electrical standards. He illustrated the nature of other researches in electrical engineering upon condensers, insulating materials, magnetic properties of steel rails, wireless telegraphy, and other subjects which have been undertaken at the Bureau, and for most of which special instruments and apparatus have had to be designed and constructed by members of the staff.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

(*Stated Meeting, Board of Managers, February 10, 1915.*)

ELECTIONS TO MEMBERSHIP.

RESIDENT.

MR. FRANK GITTELSON, 1017 Spruce Street, Philadelphia, Pa.

MR. WILLIAM J. TURNER, "Lycoming," School House Lane, Germantown, Philadelphia, Pa.

MR. S. D. WARRINER, 437 Chestnut Street, Philadelphia, Pa.

NON-RESIDENT.

MR. CHARLES EDWARD BENNETT, 59 West Twelfth Street, Atlanta, Ga.
MR. CHARLES A. TERRY, Westinghouse Electric and Manufacturing Company, 165 Broadway, New York, N. Y.

LIFE.

MR. CLARENCE E. CORNELIUS, 222 West Hortter Street, Germantown, Philadelphia, Pa.
MR. JOHN C. CORNELIUS, JR., 225 West Tulpehocken Street, Germantown, Philadelphia, Pa.
MR. JUSTICE C. CORNELIUS, 405 Wister Street, Germantown, Philadelphia, Pa.

ASSOCIATE.

MR. BARTRAM ASHMEAD OWEN, 411 Pine Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. J. J. GIBSON, care of Westinghouse Electric and Manufacturing Company, Box 911, East Pittsburgh, Pa.
DR. M. G. LLOYD, *Electrical Review and Western Electrician*, 608 South Dearborn Street, Room 1650, Chicago, Ill.
MR. JOSEPH T. MANNING, Thirty-seventh and Reed Streets, Philadelphia, Pa.
MR. TINIUS OLSEN, Hotel St. Francis, San Francisco, Cal.
MR. HENRY W. SCATTERGOOD, 530 Land Title Building, Philadelphia, Pa.
PROF. V. A. SUYDHAM, Medico-Chirurgical College, Philadelphia, Pa.

NECROLOGY.

Mr. J. B. Baker, Thirty-second Street and Powelton Avenue, Philadelphia, Pa., February 14, 1914.

Mr. J. Langcloth, P. O. Box 957, New York, N. Y., August 14, 1914.

LIBRARY NOTES.

PURCHASES.

DUBBEL, H.—High-Power Gas Engines. 1914.
GAGE, S. H. and H. P.—Optic Projection. Principles, Installation and Use of the Magic Lantern. 1914.
GREGORY, O.—Treatise on Mechanics—Theoretical, Practical and Descriptive. Three volumes. 1826.
HESS, H. D.—Graphics and Structural Design. 1913.
HUBBARD, C. L.—Power Heating and Ventilation. Two volumes. 1914.
JAMES, W. H., and DOLE, M. W.—Mechanism of Steam Engines. 1914.
LUNGE, GEORGE.—Technical Gas Analysis. 1914.

METCALF, L., and HARRISON, P. E.—American Sewerage Practice. Vol. i, Design of Sewers. 1914.

POISSON, S. D.—Traité de mecanique. Two volumes in one. 1811.

SHARP, JOHN.—Some Considerations Regarding Cast Iron and Steel Pipes. 1914.

SOUTH KENSINGTON SCIENCE MUSEUM.—Catalogue of the Mechanical Engineering Collection. Part 1, edition 5, and supplement. 1914.

VAN ORNUM, J. L.—Regulation of Rivers. 1914.

WAHL, A.—Manufacture of Organic Dyestuffs. 1914.

WRAIGHT, E. A.—Assaying in Theory and Practice. 1914.

GIFTS.

American Electrochemical Society, Transactions, 1914. South Bethlehem, 1915. (From the Society.)

American Institute of Electrical Engineers, Year-Book, 1915. New York, no date. (From the Institute.)

American Railway Master Mechanics' Association, Proceedings, vol. xlvii, parts i and ii. Chicago, 1914. (From the Association.)

British Aluminium Company, Ltd., Binder of Aluminium Publications. London, 1914. (From Mr. Arthur Seligman.)

Canada Department of Mines, Report, 1913: Report on the Building and Ornamental Stones of Canada, vol. iii. Ottawa, 1914. (From the Department.)

Canada Department of Trade and Commerce, Report, parts 2 and 3, 1914. Ottawa, 1915. (From the Department.)

Canada Public Archives, Report, 1913. Ottawa, 1914. (From the Public Archivist.)

Case School of Applied Science, Catalogue, 1914–1915. Cleveland, no date. (From the School.)

Central Electric Company, Catalogue No. 28. Chicago, 1912. (From the Company.)

Cutter Company, "When a Fuse Blows." Philadelphia, 1915. (From the Company.)

Goulds Manufacturing Company, Catalogue of Pumps. Seneca Falls, no date. (From the Company.)

Harvard University, Catalogue. Cambridge, 1915. (From the University.)

Illinois State Geological Survey, Bulletin No. 21. Urbana, 1914. (From the Survey.)

India Geological Survey, Memoirs, Series xv, vol. vii, Nos. 1 and 4. Calcutta, 1910. (From the Survey.)

Indian Meteorological Department, Rainfall Data of India, 1912. Calcutta, 1913. (From the Department.)

Iowa Geological Survey, Annual Report, 1912. Des Moines, 1914. (From the Survey.)

Iowa Railroad Commission, Thirty-sixth Annual Report. Des Moines, 1913. (From the Commission.)

Iron and Steel Institute, Journal, vol. xc. London, 1914. (From the Institute.)

Isthmian Canal Commission, Canal Record, vol. vii. Aucon, 1914. (From the Commission.)

IXL Pump and Manufacturing Company, Catalogue "C." Philadelphia, no date. (From the Company.)

K. Vitterhets Historie Och Antikvitets Akademien, Fornvannen, 1913. Stockholm, 1914. (From the Akademien.)

Lake Superior Mining Institute, Proceedings. Ishpeming, 1914. (From the Institute.)

MacArthur Concrete Pile and Foundation Company, "Concrete Pile Standards." New York, 1915. (From Mr. Hunley Abbott.)

Message of the Governor of Pennsylvania to General Assembly, January 5, 1915. Harrisburg, 1915. (From the State Librarian.)

Minneapolis Steel and Machinery Company, Catalogue B201. Minneapolis, no date. (From the Company.)

Missouri Botanical Garden, Annals, vols. 1–4. St. Louis, 1914. (From the Botanical Garden.)

Montana Railroad and Public Service Commission, Seventh Annual Report. Helena, 1914. (From the Commission.)

Mount Holyoke College Catalogue. South Hadley, 1914. (From the College.)

Murray Iron Works, Pamphlet No. 12. Burlington, no date. (From the Company.)

National India Rubber Company, Catalogue of Insulated Wires and Cables. Bristol, no date. (From the Company.)

National Machinery Company, Catalogue E. Tiffin, no date. (From the Company.)

New Process Twist Drill Company, Catalogue of Drills. Taunton, 1915. (From the Company.)

New South Wales Vital Statistics for 1913. Sydney, 1914. (From the Government Statistician.)

New York General Education Board, An Account of its Activities, 1902–1914. New York, 1915. (From the Board.)

New York Public Service Commission, Report, vol. i, 1913. Albany, 1914. (From the Commission.)

Oklahoma Geological Survey, Bulletins Nos. 13, 18, 21, 22. Norman, 1914. (From the Survey.)

Pennsylvania Board of Public Charities and Committee on Lunacy, Report, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioner of Banking, Nineteenth Annual Report, part 2, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioner of Health, Annual Report. Harrisburg, 1910. (From the State Librarian.)

Pennsylvania Department of Agriculture, Report, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Department of Mines, Reports, parts 1 and 2, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Secretary of Internal Affairs, Annual Report, parts 1 and 2, 1913. Harrisburg, 1914. (From the State Librarian.)

Pratt Institute, Catalogue, 1913–1914. Brooklyn, no date. (From the Institute.)

Princeton University Observatory, Contribution No. 3, "A Study of the Orbits of Eclipsing Binaries." Princeton, 1915. (From the Observatory.)

Smithsonian Institution, Annual Report, 1913. Washington, 1914. (From the Institution.)

Sturtevant, B. F., Company, Catalogue No. 195. Boston, 1914. (From the Company.)

Tasmania Department of Mines, Geological Survey Bulletin No. 18. Tasmania, 1914. (From the Department.)

Thomas, R., and Sons Company, Catalogue No. 12. East Liverpool, no date. (From the Company.)

United States National Museum, Report, 1914. Washington, 1915. (From the Museum.)

United States Surgeon-General's Office, Index-Catalogue of The Library, Second Series, vol. xix. Washington, 1914. (From the Surgeon-General.)

University of Pennsylvania, Catalogue. Philadelphia, 1914. (From the University.)

Verona Tool Works, Catalogue No. 11. Chicago, no date. (From the Company.)

Washington Public Service Commission, Fourth Annual Report. Olympia, 1914. (From the Commission.)

Wesleyan University, Catalogue. Middletown, 1915. (From the University.)

Wiley & Russell Manufacturing Company, Catalogue No. 36. Greenfield, 1914. (From the Company.)

BOOK NOTICES.

IOWA STATE UNIVERSITY, BULLETIN, NEW SERIES No. 87. University Extension Bulletin No. 8. Bureau of Municipal Information. Water Works Statistics of Thirty-eight Cities of Iowa, with the Meter Rates of Seventy Cities. By John H. Dunlap. Iowa City, University. 52 pages, 8vo.

The administration of American municipalities is the despair of efficiency engineers, and in no respect is the difficulty greater than in the control of water supply. American communities are notorious water-wasters, and privilege and silly sentimentality ("water should be as free as air") interfere with business methods. Data such as are included in this pamphlet will be of use in presenting correct notions. H. L.

MODERN INSTRUMENTS AND METHODS OF CALCULATION. A handbook of the Napier Tercentenary Exhibition. Edited by E. M. Horsburgh. Pp. vii and 343. Illustrations. 8vo. London: G. Bell and Sons, Ltd., and The Royal Society of Edinburgh. No date. Price, 6s. net.

The valuable collection of mathematical books, tables, and instruments available for inspection at the Napier Tercentary Exhibition, held by The Royal Society of Edinburgh to celebrate the three hundredth anniversary of the publication by John Napier of his Canon of Logarithms, forms the basis of construction of this book. The first chapter deals with the life and inventions of Napier himself, and there follow two sections made up of catalogues of the exhibition. The major part of the book contains articles by specialists on calculating machines, the abacus, slide rules, and other mathematical laboratory instruments, including integraphs, planimeters, harmonic analyzers, and a tide predicter. Chapters on ruled papers, nomograms, and mathematical models conclude the work. The chapters relating to calculating mechanisms include the latest form of adding and listing machines and adding and subtracting typewriters. The book is of value to all who are interested in mechanical calculation.

W. E. BULLOCK.

PUBLICATIONS RECEIVED.

Annuaire pour l'an 1915 publié par le Bureau des Longitudes, Avec une notice scientifique. 995 pages, illustrations, maps, 24mo. Paris, Gauthier-Villars, no date. Price, 1 franc 50c.

Canada Department of Mines, Mines Branch: Production of Cement, Lime, Clay Products, Stone, and Other Structural Materials in Canada during the Calendar Year 1913. 62 pages, 8vo. Production of Iron and Steel in Canada during the Calendar Year 1913. 44 pages, 8vo. Ottawa, Government Printing Bureau, 1914.

U. S. Bureau of Mines: Monthly Statement of Coal-mine Fatalities in the United States, October, 1914, with revised figures for preceding months. Compiled by Albert H. Fay. Washington, Government Printing Office, 1915.

Density of Wood Substance and Porosity of Wood, by Frederick Dunlap, Forest Assistant, Forest Products Laboratory, Forest Service. Reprint from *Journal of Agricultural Research.* 6 pages, 8vo. Washington, Department of Agriculture, 1914.

Leavening Agents: Yeast, Leaven, Salt-raising Fermentation, Baking Powder, Aërated Bread, Milk Powder, by Richard N. Hart, B.S. 90 pages, illustrations, 8vo. Easton, Pa., The Chemical Publishing Company, 1914. Price, $1.

Potassium Oxide in California. ANON. (*Oil, Paint, and Drug Rep.,* Sept. 7, 1914.)—The first American potash will be produced by the Searles Lake plant within three months. The initial output will be only about 5 tons per day, but the plant under construction is expected to produce 120 tons per day.

CURRENT TOPICS.

Use of Pulverized Coal in the Cement Industry. R. C. CARPENTER. (*Amer. Soc. Mech. Engin. Journal*, xxxvi, p. 337.)—The author devotes a large portion of this paper to the history of the development of the process for burning pulverized fuel in cement kilns in the United States. Hurry and Seaman were the first to apply the new method successfully, in the years 1894–95, in the cement works of the Atlas Company. According to the author no inventors prior to Hurry and Seaman had comprehended the essential condition of success for burning pulverized fuel in furnaces; namely, that the fuel must be burned completely while in suspension, and that the utilization of the heat of combustion must be by radiation from the flame, and not by impingement of the flame on the bridge or walls of the furnace. The failure to recognize this condition of success is, he states, in a large measure responsible for the practical failure of the burning of pulverized fuel in boiler furnaces, although such furnaces, because of their form and proportions, render more difficult the problem of burning coal-dust in suspension. In practically all of the devices which have been tried under boilers the flame has impinged on the bridge-walls or sides of the furnace, or on portions of the boiler, before the combustion was completed, with the results that fuel was wasted, capacity was reduced, and the linings of the fire-box or other portions on which the flame impinged were destroyed. Since 1902 the use of pulverized coal for heating the rotary kilns has become general in the cement industry, and operations and machinery used have become standardized. They are considered and described under the following headings: (1) Drying; (2) Pulverizing; (3) Conveying; (4) Storing; (5) Feeding.

An Ideal Rubber Factory. A. DOUGLAS. (*India Rubber Journ.*, xlviii, 18.)—The greatest possible cleanliness must be aimed at, and certain precautions in factory-design and equipment are enumerated. There must be no bright light, which darkens the rubber, and no dark corners to harbor fungi. Rain water should be collected and used for dilution of latex and acid. Smoke chambers should be of wood, with heavy corrugated iron roofs, lined with sacking. The procedure recommended for the production of smoked sheets is as follows: The latex is diluted to standard gravity and mixed in a white-tiled tank. From 0.7 to 1 per cent. of its bulk of 10 per cent. acetic acid is added, and the mixture stirred with a glass rod, and then transferred in pails to the pans, which, when full, are skimmed and dividing boards introduced. On the following morning the

coagulum is gently pressed until about three-fourths of an inch thick, then reduced to ordinary sheet thickness by three or four passages through smooth rollers, and finally once through marking rollers. The sheet is drained on racks for two hours, then smoked. Decayed timber and cocoanut husks form good fuel. The rubber is ready to pack in ten days. In making thick crêpe the rubber is first sheeted between rollers, dried, and re-rolled thick in diamond rollers and dried further. It is ready for packing in twenty-one days.

The Influence of Allotropy on the Metastability of Metals, and its Bearing on Chemistry, Physics and Technology. E. COHEN. (*Faraday Society*, Nov. 23, 1914.)—Experiments made with pure cadmium are described, measurements being made with the pyknometer, the dilatometer, and with low-voltage standard cells in which the negative electrode consisted of cadmium deposited electrolytically on a platinum spiral. The results show that ordinary cadmium contains three allotropic forms. Density and dilatometric measurements made with pure lead indicated for this metal also the simultaneous presence of more than two allotropic forms. The conclusion is drawn that the pure metals (Cd, Pb, Bi, Cu, Zn, Sb), as known until now, are metastable systems consisting of two (or more) allotropic forms. This is a consequence of the very strongly marked retardation which accompanies the reversible change of these allotropic modifications below and above their transition points. All the physical and mechanical constants of metal hitherto determined thus refer to complicated metastable systems, which are entirely undefined, as the quantities of the α, β and γ modifications they contain are not known. The reversible transformations of one modification to another must play an important rôle when metals are subjected to changes of temperature. If the metals are in contact with electrolytes (water), the transformation velocity is enormously accelerated, and the volume changes which generally accompany these transformations may cause the disintegration of the metals. These phenomena must be taken into account in cases where corrosion occurs.

Martensite Structure of Steel. C. H. DESCH. (*Faraday Society*, Nov., 1914.)—By slowly cooling an overheated steel (C 0.28 per cent.) a martensitic structure was obtained without increase of hardness; by examination with an immersion objective, the whole mass was found to consist of pearlite packed closely in some parts and loosely in others. The view of Edwards and Carpenter that martensite and austenite are constitutionally identical, the former being repeatedly twinned, and its hardness due to the formation of amorphous material at the surface of slip on which twinning occurs, is rejected, and it is considered that the martensitic structure is an accompaniment, and not the cause, of the hardness of a quenched steel, martensite being so much harder than its components as to suggest the presence of a solid solution.

Interstrain Theory of Hardness of Metals. A. MCCANCE. (*Faraday Society*, Nov., 1914.)—Pure iron, like other metals, is hardened when strained so as to cause permanent deformation. The iron is then in a condition of "interstrain," in which the arrangement of the atoms in the original crystalline structure is so far disturbed that the atoms can no longer return to their positions of equilibrium, and it is this condition which is considered to involve increased hardness; under strain α-iron remains magnetic and γ-iron non-magnetic, showing that the metal is not merely reduced to an amorphous structure by strain, but retains the distinguishing properties which are the result of crystalline form. To harden steel by quenching, it must be heated to the temperature at which the carbon is all in solution, and the greatest hardness is obtained when the temperature reaches the highest change point. The maximum hardness is obtained with C 0.7 per cent.; since the hardness is not proportional to the amount of carbon dissolved, the action of the carbon is indirect. Steel, which is non-magnetic at the temperature of quenching, becomes magnetic in the hardened state, owing to the conversion of γ- into α-iron. With a given rate of cooling this change of crystalline structure stops at a point determined by the increase in the internal viscosity at the lower temperature, and in this way a condition of interstrain is produced involving increased hardness. Tempering removes the condition of interstrain.

America's Mineral Products.—The mineral products of the United States are discussed in a small volume now being distributed by the United States Geological Survey which contains a fund of useful information concerning the useful minerals and their values and production in all the States during 1912 and 1913. The figures given in some of the tables are so stupendous as to be beyond comprehension. In one table are given the figures for mineral production from 1880 to 1913, the metals being valued at $185,000,000 in 1880 and increasing to $883,000,000 in 1913. The nonmetallic minerals increased from $173,000,000 in 1880 to $1,562,000,000 in 1913, and the total mineral production from $365,000,000 to $2,446,000,000. This total for 1913 was an increase over 1912 of more than $200,000,000. The value of the metals imported for consumption in 1913 was $237,000,000 and of those exported $319,000,000. The value of the total mineral production from 1880 to 1913, inclusive, was $35,197,000,000.

These huge figures are of general interest, but the chief value of the volume lies in the figures and discussion of the increased or decreased production of each State during recent years. Seventy principal minerals are discused in the pamphlet, entitled "Mineral Products of the United States in 1912 and 1913," a copy of which may be obtained free of charge from the Director, U. S. Geological Survey, Washington, D. C.

The Theory of Bleaching. S. H. HIGGINS. (*J. Soc. Dyers and Col.*, xxx, 326.)—The bleaching action of hypochlorous acid is due initially to the direct production of oxygen, but, as the bleaching proceeds, hydrochloric acid accumulates and reacts with hypochlorous acid according to the equation, $HOCl + HCl = H_2O + Cl_2$. This action is reversible, the reverse direction representing the behavior of chlorine water, and in each case when equilibrium occurs the bleaching action ceases. When a hypochlorite is used for bleaching, the hypochloric acid produced is used in liberating more hypochlorous acid. The removal of free hydrochloric acid from either chlorine water or hypochlorous acid by addition of calcium carbonate has been shown experimentally to accelerate the bleaching action. Taylor's observation that there is always a certain amount of residual color in cotton treated with hypochlorous acid or chlorine water is explained by this state of equilibrium; when calcium carbonate is added, the cotton is completely bleached. The coloring matters of brown linen and of boiled cotton are at once partially bleached on immersion in chlorine water, but prolonged treatment has very little further effect. The action of bleaching powder solutions on cotton dyed with direct and basic dyestuffs has been examined; in a number of cases the solutions to which hydrochloric acid was added caused a change of color, while when boric acid was added no such change was observed. In the majority of cases the solutions containing hydrochloric acid had the more rapid bleaching action; with alizarin sapphirole, however, the reverse was the case. The author concludes that the bleaching action of hypochlorites is due to the direct production of oxygen and to the production of nascent chlorine. Thus, it has been found that a large quantity of acetaldehyde is produced on warming dry calcium hypochlorite with alcohol, while it is known that bleaching powder can convert alcohol into chloroform. It is considered that the nascent chlorine is formed by the interaction of the chloride with the free hypochlorous acid. The effect of the calcium chloride produced during bleaching with bleaching powder is shown to be negligible, but when calcium chloride is added during the bleaching process it always has a stimulating effect, showing that hypochlorous acid is present during the whole process. Attention is drawn to the importance of using carefully-prepared fibre in bleaching experiments, and of making allowance for the fact that the coloring matters of cotton and linen are of an acid nature, especially in comparing the bleaching actions of acid and alkaline solutions.

Italian Petroliferous Zone. B. GALDI. (*L. Ind. Chimica. Min. e Metall.*, i, 264.)—The petroleum industry in the province of Emilia has worked successfully with a moderate profit, and systematic prospecting for petroleum throughout the whole of southern Italy is now recommended.

The Sale of Tar. (*Chem. Trade J.*, Nov., 1914.)—The following conditions relative to the sale of tar have been agreed upon by the joint committee of the Institution of Gas Engineers representing tar producers and distillers, and are recommended for adoption throughout the United Kingdom:

I. *Sliding-scale Contracts.*—(*a*) The tar distillers and gas authorities, or their valuers, to meet each month as usual, to fix the values of the products other than pitch. (*b*) The tar distillers to pay to the tar producers the aggregate value of such products, *plus* 2s. 6d. per ton of tar on account, for the pitch, less the usual 2½ per cent. and working expenses. (*c*) All pitch made and delivered since August 1, 1914, by individual tar distillers during the period of crisis to be paid for each month *pro rata* to the deliveries of tar of each producer, allowance being made for the 2s. 6d. per ton of tar already paid on account. (*d*) On the resumption of the export of pitch at present suspended, the value of such pitch delivered each month to be settled by the usual arbitrators, and the value ascertained each month to be added to the tar values and paid by the tar distillers to the tar producers, less the 2s. 6d. per ton of tar already paid on account. (*e*) The additional cost (if any) incurred by the removal and storage of pitch to be equally borne by the tar producers and the tar distillers.

II. *Price-fixed Contracts.*—(*a*) The sum of 17s. 6d. per ton of tar to be paid by the distillers and accepted by the producers in part payment as the value of products other than pitch and part value of pitch. (*b*) The balance to be paid as and when the pitch is delivered by the distillers *pro rata* to the deliveries of tar of each producer.

III. *Minimum Price of Pitch.*—A committee has been appointed to consider and, if advisable, to fix prices from time to time.

IV. *Revision of Conditions.*—These conditions may be amended by mutual arrangement between the tar producers' committee and the tar distillers from time to time.

The Veritas Firing Rings as Pyrometers. A. V. BLEININGER and G. H. BROWN. (*Trans. Amer. Ceram. Soc.*, xvi, 222.)—The principle involved in the use of these rings, invented by M. Solon, is the same as in the pyrometer devised by Josiah Wedgwood: that of shrinkage in fire. A clay body similar in composition to white ware (roughly, clay 52, flint 33, felspar 15 per cent.) is formed into rings 2.5 inches in diameter, with a hole 0.85 inch diameter. Progress of firing is followed by the withdrawal of rings from various parts of the kiln. The rings share the properties and defects of Seger cones, but are more useful in the early stages of the fire, as they swell up before dehydration, whereas a cone shows nothing until incipient softening by fusion occurs. Rings of a former batch should be preserved in order to check the behavior of the next batch.

The True Value of Sodium Perborate Bleaching. W. KIND. (*Z. Ges. Textil. Ind.*, xvi, 1045.)—Although the perborate cannot compete with the chlorine bleach on the ground of cost, yet it has advantages over hydrogen peroxide, mainly on account of the ease with which a solution of the required strength can be made up and the way in which it gradually gives up its oxygen without the development of too great a degree of alkalinity. Perborate has advantages for special purposes in bleaching, *e.g.*, for colored and finished goods. As a starch remover it can compete in certain circumstances with "Diastafor." It destroys active chlorine, but not chloramines. In dyeing it is used for after-treating vat and sulphide dyes, in cleaning for removing stains and for bleaching feathers, etc. It has found its greatest application in the laundry on account of being safer than the chlorine bleach. Generally its use in ordinary bleaching is too expensive.

Applications of Tar and its Derivatives. KAYSER. (*J. Gasbeleucht*, lvii, 200.)—Owing to the large amount of benzene for use in dye manufacture recovered in the production of coke in coke-ovens, new outlets are necessary for the tar and its derivatives produced in gas works. The use of tar oil as fuel in furnaces and engines is one such. In furnaces the oil should be supplied under pressure and then broken up by air streams. A flat stream issuing under low pressure appears better than spraying through easily-choked, fine orifices. In the Irinyi apparatus the oil is vaporized in a retort in the furnace, oil flowing to the retort by gravity. The advantages of tar-oil in furnaces are smokeless firing, simplicity of working, and cheapness. Tar oil is also used in Diesel engines, and Körtings's have a plant of 500 horse-power running with tar from vertical retorts; this works as well as a tar oil installation, while the cost of fuel is less, but a special starting means is necessary. Tar has also been used in furnaces. Tar is in demand for road making and for coating wood, etc., especially in roof work. Pitch is used in the coal briquetting industry. Separate works for the distillation of 175 to 200 tons of tar per annum are not profitable. Combined working of such outputs should be resorted to. Both continuous and discontinuous distillation processes are used. A continuous plant of H. Hirzel comprises a raised reservoir into which tar is pumped, and whence it flows through a vertical chamber having horizontal baffles and heated to 180° C. to drive off water and light oils. It then passes through a series of three stills, placed side by side and stepwise. In the first medium oils are driven off; in the second, heavy oils, and in the third, anthracene, the pitch being drawn off through a cooler into pits. The distillates are passed through condensers into reservoirs. A fourth still is used alternatively as the third in the series, and alternate cooling tanks are used for the pitch. In the discontinuous process a vertical retort is usual, the means for driving off water and light oils being the same as in the continuous

process. For large plants a vacuum process is desirable. In the Sadewasser system, tar in a continuous stream is passed through a superheater and sprayed in a vacuum chamber; the ensuing vapor is condensed in fractional cooling chambers. Pitch is suggested as an alternative to cement for building purposes.

Effects of Pressure on Distillation of Hardwood. R. C. PALMER. (*J. Ind. Eng. Chem.*, vi, 890.)—Experiments were made with maple and birch sawdust and birch chips 1 × ⅛ × ⅛ inch in size, distillation being effected in a cast-iron autoclave, 15¼ inches deep by 8¼ inches inside diameter. The effect of pressure was to increase the yield of charcoal and gas and, to a slight extent, of wood alcohol, and to decrease the yield of acetic acid, pyroligneous acid, and tar. A greater effect was produced by increasing the pressure from atmospheric to 60 pounds than by a further increase. The greatest effect was on the yield of tar, which was decreased 60 to 65 per cent. at 60 pounds pressure. It is suggested that possibly pyroligneous acid free from soluble tar might be obtained by subjecting the distillate to high pressure during the vapor stage.

Comparison of Engler's and Barbey's Viscosimeters. C. BAHEUX. (*Les Matières Grasses*, vi, 3221.)—Barbey's ixometer measures the fluidity of an oil, but does not give information of the behavior of a lubricating oil in practice. In the case of machine oils, whose fluidity is usually determined at 35° and 50° C., the results are concordant, but for testing cylinder oils (100° C.) Engler's viscosimeter is preferable, since less time is required. Moreover, the use of an oil-bath with the ixometer involves considerable error due to the irregular distribution of the heat, whereas the heating bath of Engler's apparatus is easily regulated. The values obtained with the two apparatuses do not agree in all cases, the friction coefficient being greater in the case of Barbey's apparatus, which has a much longer outlet tube. Of two oils with equal viscosity, that with the smaller friction coefficient will pass more readily through the outlet tube of Barbey's apparatus than the other. This is particularly noticeable with compound oils, the friction coefficient of which is lower than that of mineral oils of equal viscosity. Only mineral oils of the same viscosity that have been refined, etc., in the same way can be compared by means of Barbey's apparatus. Engler degrees may be calculated into Barbey's degrees by the formula: $f = \frac{720{,}000}{v.a.M.}$ where f represents the Barbey fluidity degree, v the Engler viscosity, a the efflux velocity (seconds in Engler's viscosimeter) of 200 c.c. of water at 20° C., and M a factor varying with the temperature and the quality of the oils. The results agree well in the case of mineral oils at 50° and 100° C., but are not applicable without correction to oils tested at 35° C., or to compound oils.

The Auto Truck on Geodetic Work.—An unusual feature of the work of the United States Coast and Geodetic Survey, Department of Commerce, during the past summer was the successful use of a 1½-ton automobile truck in transporting an astronomical party and outfit through a portion of the Southwest which is generally dreaded by the transcontinental tourist. The party was in charge of Mr. C. V. Hodgson and was in the field from May to October. The trip is the more remarkable when the fact is taken into consideration that the requirements of the work prevented a close adherence to the routes usually followed. Observations were frequently made on mountain peaks, so the journey was from mountain to mountain, rather than along main travelled roads from city to city.

The general route followed by Mr. Hodgson and his party was from Denver, Colo., to Pecos, Texas, then southwest almost to El Paso, where a detour was made over poor trails through southern New Mexico into Arizona. The central and southern portions of the latter State were rather well covered, the itinerary including Solomonsville, Douglas, Benson, Tucson, Globe, Phœnix, Yuma, and Parker. The auto truck was then driven across California to San Diego and the San Jacinto Mountains, thence via Los Angeles, Mojave, and Sacramento to Carson City, Nev. Astronomical observations were carried along the California-Nevada boundary to Needles, Cal., the terminus of the journey. During the season the truck, carrying a capacity load, was run more than 5000 miles under road conditions varying from the deep mud encountered in New Mexico and Texas, and the heavy sands of the Colorado River and Nevada desert regions, to the splendid roads of southern and central California.

On a canyon road in western Texas Mr. Hodgson's party and outfit had a narrow escape when a small cloudburst in a few minutes transformed the road into a river, as the water came rushing down the canyon from the mountains above. There was no time to put on chains, but ropes were quickly wrapped around the rear wheels and the truck was run up a steep slope until stalled in the rising and rushing water. The truck was then moored to mesquite bushes and the outcome awaited with considerable anxiety, but the water soon ceased to rise and the danger was past. Had the truck remained where the water first struck it, it would have been almost completely submerged and probably overturned and damaged by the drifting timbers.

It was in the desert sands, however, that the greatest difficulties were encountered, as the truck was fitted with ordinary solid rubber tires (dual behind) which cut in deeply. Many expedients were tried, but the most successful one was the use of green poles placed in front of the dual-tired rear wheels in as rapid succession as

possible. These poles gave traction and kept the wheels from sinking into the sand. The extreme heat, often reaching 115° in the shade, made such work very trying.

The cost sheets of the season show that the work was done at a saving of at least 35 per cent. from the cost had teams been used. The cost per mile for oil and gas varied from 2.7 cents to 6.6 cents in different sections of the country, and averaged 3.9 cents for the entire season.

A remarkable feature of the performance of the truck and a tribute to the good work of the driver was the fact that, from the time of leaving Colorado Springs to the end of the season, about six months, during which the truck was run over 5000 miles, only two hours were lost on the road on account of engine troubles.

Corrosive Action of Electrical Currents on the Gas and Water Mains in the Town of Gablenz a. N. (Austria). T. HERRMANN. (*J. Gasbeleucht,* lvii, 88.)—Attention is drawn to the serious electrolytic corrosion of water and gas mains in Gablenz. The origin of the earth currents is attributed to the electric tramways in the streets. These vagrant currents are assisted by impurities introduced into the soil through acids formerly discharged by factories in various places. The damaged pipes are for the most part situated under the tram rails, and cast- and wrought-iron tubes were equally attacked. In a large number of lead pipes the metal was transformed into a brown powder, whereby serious leaks of gas occurred. The accumulation of gas led, in one instance, to a disastrous explosion. Especial damage has been caused at the gas works, where many lines converge, through stray currents travelling along the main pipes connected with the plant. The water conduits and oil pumps were thus destroyed. Accidents also arose from the difference in potential existing between the earthed gas plant and the tram rails, which led to discharges between the two. In addition to electrolytic actions, a number of accidents have arisen through lightning discharges. These have struck the overhead live wires, or, in some cases, exposed metal fittings, and created a short circuit between the electrical leads and the gas mains or telephone wires. The disturbances at the gas works have been obviated by suspending electrical traction altogether and by interrupting the metallic connection between the street mains and the gas works. This has been effected by the use of flanged joints between the pipes, packed with layers of mica. This method has introduced an additional danger on account of lightning discharges. Electrical charges concentrated in the ground surrounding the works tend to pass along the whole length of pipes as offering the path of least resistance to distribution in the earth; currents thus tend to leap over the insulated section and cause dangerous discharge at the metallic termini. The parasitic earth currents arise from the difference in potential—in some cases amounting to 20 volts—between the tram rails and adjacent pipes, and these can best be minimized by

lowering this potential. It is desirable, therefore, to increase the conductivity of the rails. Short circuits by lightning discharges can be obviated by more carefully arranged installations.

U. S. Geological Survey at the Panama-Pacific.—The central feature of the United States Geological Survey's exhibit at the Panama-Pacific Exposition, in San Francisco, will be two stagelike settings—partly model and partly painted—representing a district in the arid West both before and after development. In the before-development scene topographic engineers are at work with their instruments on the headlands, geologists have stripped a bed of coal and are taking samples for analysis, and other geologists are studying rock formations. In the foreground is an automatic river gauge; farther back a hydrographer is measuring the flow of the stream as it races by. In the background is a camp and pack train.

The second scene shows the same district after development. The results of the stream gauging have been utilized in planning a power plant that shows in the distance and an irrigation project that covers the valley floor. The coal bed is being mined, an oil field with derricks is under development, a sandstone bed is being quarried, and mining and milling are in progress in the mountains. A town has also sprung up and roads, railroads, and other evidences of civilization abound.

The scenes are illustrative of the basic work of the Geological Survey and also explain why this organization is not even better known than it is. It carries on the pioneer work and prepares the way for the engineer and the constructor; but when these men appear on the ground to erect permanent monuments to their professions, the Survey disappears from the scene and moves on to new fields.

Gas Lighting and Hygiene. M. VON GRÜBER. (*J. Gasbeleucht*, lvii, 690.)—Tests were carried out in rooms in which the conditions could be controlled. Sulphur dioxide and carbon monoxide could not be detected in the air in the rooms, even after the burners had been alight for 67 hours; traces of nitric oxide were usually present, the largest amount found being 10.4 c.c. per cubic metre. The quantity of carbon dioxide never exceeded 4 parts per 1000, and the temperature of the rooms was raised only a few degrees. In comparative experiments with gas and electric lights, the difference in the increase of the temperatures of the rooms amounted to 1.6° C., while the difference in moisture content of the air was generally less than 5 per cent. In the room lighted with electric lamps the ventilation was such that about one-third of the air was replaced per hour; in the room having gas lamps two-thirds of the air was replaced per hour. The hot gases from the lamps did not appear to have any disinfecting effect on the air.

Electrical Removal of Tar from Gas. F. W. STEERE. (*J. Gas Lighting*, cxxviii, 309.)—When crude coal gas or producer gas is submitted to an alternating high-tension discharge at 40,000 to 80,000 volts in an ionizer, the tar fog condenses to large globules, which can readily be removed by a centrifugal or by a Pelouze and Audouin extractor. In an experimental apparatus treating 30,000 cubic feet of gas per hour rich coal gas given off during the earlier part of the coking period was passed through a washer-cooler and then through the ionizer. The best temperature was 65° to 80° C. (149° to 176° F.). The naphthalene was separated in crystalline form by passing the tar-free, warm gases from the tar extractor through a washer-cooler, and the cooled gas contained only sufficient naphthalene vapor for saturation at the temperature of the gas. The separated tar contained little benzene and toluene, a larger proportion of these constituents remaining in the gas and increasing its illuminating power. This effect was increased by raising the temperature at which the gas entered the ionizer. The process has been used continuously since January, 1914, for removing tar from producer gas for use in engines.

Radium, Uranium, and Vanadium.—The year 1914 was an eventful one in the industry of mining radium, uranium, and vanadium ores and had by far the largest year's production yet made. Figures collected by Frank L. Hess, of the United States Geological Survey, indicate that the output amounted to about 4300 short tons of dry ore carrying 87 tons of uranium oxide and 22.4 grammes of metallic radium. The ore was valued at about $445,000. The ore produced in 1913 contained 41 tons of uranium oxide and 10.5 grammes of radium, and that produced in 1912 contained 26 tons of uranium oxide and 6.7 grammes of radium. About nine-tenths of the contained radium is thought to be recoverable under improved processes.

Although carnotite, a mineral of these rare metals, contains three times as much uranium oxide as vanadium oxide, the Colorado and Utah ores of these metals generally contain other vanadium minerals in such quantity that vanadium oxide is present in excess of the uranium oxide. However, little is paid for the vanadium, as its separation from uranium is troublesome, and only a few thousand dollars was received in 1914 by brokers or producers for the vanadium in the ores sold. Sandstone impregnated with roscoelite, a vanadium-bearing mica, is mined at Vanadium, San Miguel County, Colo., on the eastern edge of the carnotite field, by the Primos Chemical Company. The total quantity of vanadium in the carnotite and other ores mined during the year was apparently about 432 tons.

About the beginning of 1914, owing to the very high prices charged for radium salts, their scarcity, their evident usefulness in treating cancer and other hitherto incurable diseases, the practical impossibility of the poor receiving treatment by radium because of

its scarcity and high cost, and to the fact that much of the radium-bearing ore was being shipped out of the country, Secretary of the Interior Lane caused to be introduced in Congress bills reserving radium-bearing lands from entry as mining claims, and providing for government purchase. The bills are still pending.

During the year the National Radium Institute conducted, under the supervision of the Bureau of Mines, mining operations at Long Park, near Paradox Valley, in Montrose County, Colo., and a plant at Denver for the production of radium and investigation of processes. The work has been so encouraging that Director Holmes has announced the probable production of radium at one-third of its present cost. Messrs. Lind and Whittemore, of the Bureau of Mines, state that their investigations show that carnotite carries proportionally to its content of uranium as much radium as pitchblende or other uranium minerals; that is, the radium has reached its maximum ratio to the uranium from which it is derived and is thus in equilibrium. From published results of experiments made on casual specimens of carnotite it had been popularly supposed that carnotite was less rich than pitchblende in radium.

In Utah the Standard Chemical Company made the first commercial production of carnotite ores from the Henry Mountains during the year, and the commercial production of uvanite, a radium-bearing mineral new to science, accompanied by other uranium minerals, one or more of which are yet to be described, was begun at Temple Rock, 45 miles southwest of Green River. Shipments were made from newly-opened carnotite deposits at Court House, northwest of Moab, Utah, and from deposits 16 or 18 miles southeast of Moab. A first shipment was also made from Blue Mountain, Routt County, Colo.

The Paradox Valley region was, however, as usual, the chief producing area, and from it came the bulk of the ores. The Standard Chemical Company was the largest single producer and shipped more than half of the country's output.

Two companies, the Standard Chemical Company and the Radium Company of America, produced radium salts during the year, and Dr. W. A. Schlesinger started a radium-refining laboratory. The opening of the European war stopped nearly all operations in both mines and reduction plants, for the two companies mentioned sold their product largely in Europe and practically all the ore bought by brokers was sold abroad. A little more than 1200 tons of ore, containing 28.1 tons of uranium oxide and 7.2 grammes of radium, was consigned to Europe, but, as the foreign refineries were closed, a part of it was held in transit.

No vanadinite or similar ores are known to have been sold for vanadium during the year, but a number of mines in New Mexico and Arizona shipped and sold such ores for their lead and silver contents.

Iron-titanium Alloys. J. LAMORT. (*Ferrum*, xi, 225.)—The equilibrium diagram of these alloys has been studied by the methods of thermal analysis. Alloys containing up to 24 per cent. Ti were prepared by melting ferro-titanium with mild steel in a kryptol furnace. The liquidus consists of two branches meeting in a eutectic point at 1300° C. and a composition of about 13 per cent. Ti. Iron retains about 6 per cent. Ti in solid solution. Microscopic analysis confirms the results of the thermal study, and also indicates the existence of a compound Fe_3Ti. Study of the magnetic properties showed that the temperature of the magnetic change is lowered by the addition of Ti. The curve showing the relationship between temperature of magnetic change and the Ti content is practically a straight line running from 0 per cent. Ti and about 787° C. to 21 per cent. Ti and 690° C. The presence of nitride and cyanonitride can be recognized readily under the microscope. The effect of additions of titanium to iron and steel most likely depends on whether the Ti exists in the alloy in the metallic state or in the form of nitride. This probably accounts for the variations in the results obtained by different workers in this field.

Locomotive Head Lamps. J. L. MINICK. (*Electr. World*, lxiv, No. 14, 656.)—The chief function of a locomotive head lamp is to warn persons on the track ahead that a train is approaching. A lamp having a centre-beam intensity of 500 candle-power can be seen 25 miles away by a person of average height, therefore it will give 25 minutes' warning of the approach of a train running at 60 miles an hour (on a straight track, with nothing to obscure the light! [abstractor]). To prevent blinding persons looking towards the lamp, the intensity of the light should not be higher than 15 or 20 candle-power per square inch of projected area. A 3000-candle-power lamp with a 16-inch reflector will have an intrinsic brilliancy within the maximum value. Second in importance among the functions of a head lamp is its ability to illuminate whistle posts, landmarks, etc., properly. These need not be illuminated with an intensity higher than 0.10 foot candle. This intensity will be produced by the side rays from a 500-candle-power lamp when the marker is about 50 feet ahead of the locomotive. No commercially available lamp will enable an engineer to see a dark object ahead in time to stop his train, as a dark dummy can be seen at night only 500 feet away when illuminated by an incandescent head lamp of 10,000 candle-power, and a train containing 12 standard steel coaches running 60 miles an hour cannot be stopped inside of 1660 feet with the most modern air-brake rigging, or 1235 feet with the electro-pneumatic system now being developed. Attention is also called to the fact that an intense head lamp will hinder flagmen and passing engineers seeing the train classification markers, and may even blot out or alter the color of semaphore signal lamps, etc. Valuable references on tests of and regulations on head lamp intensity were included in the paper.

Felspar Supply of the United States. A. S. WATTS. (*Trans. Amer. Ceram. Soc.*, xvi, 80.)—The demand for pure felspar being greater than European sources can supply, the author recounts the location and extent of felspar deposits (apparently pegmatite) in the United States east of the Mississippi River. The influence of the methods of mining and grinding upon the quality of the finished product is shown by the good reputation of Maine felspars, which are not naturally very pure on account of a quartz content which cannot be eliminated. Analyses given of American spars show variations in alkali content from 8 to 16 per cent. The chief States concerned are Maine, Connecticut, New York, and Pennsylvania. In the last-named the largest deposit of soda felspar in the world was found, but is almost exhausted. Maryland is expected to supply soda felspar in the future; the soda pegmatites contain 6 per cent. Na_2O and 4 per cent. K_2O. In Virginia and North Carolina felspar has been subsidiary to mica mining hitherto. In Georgia the production of felspar has not yet been attempted.

Coal Consumption of New York's Generating Stations. ANON. (*Electr. World*, lxiv, No. 14, 660.)—The average consumption of fuel in all the central stations of New York City is at the rate of 3.3 pounds per kilowatt-hour, inclusive of all standby and other losses. The average consumption of fuel by insolated plants is at the rate of not less than 10 pounds of coal per kilowatt-hour, or three times the average rate of central-station operation, according to a committee of the Association of Edison Illuminating Companies. Compared with insolated plants, central-station generation of electricity is conserving in New York City alone about 1,750,000 tons of fuel a year by superior economy in production.

Measurement of Air Velocities, Pressures and Volumes. W. CRAMP. (*Manchester Lit. and Phil. Soc. Mem.*, lviii, 7, 1.)—For various reasons the anemometer is unsatisfactory in measuring air velocities; it is rather an indicator. The Pitot tube is accurate, provided the facing tube is small and of such a form that stream-line flow is not much disturbed. Various tubes are compared; the Nipher collector is very inaccurate, and the Brabée tube seems superior to anything but the Standard Pitot with static tube in pipe wall. This latter involves holes with good internal surfaces to be drilled at various points, and is often impossible in commercial work. The Brabée tube seems very little affected by faulty setting. In determining the volume of air passing through a pipe, the author takes the central velocity x as a coefficient to give the mean velocity. For central velocities of 6.89, 7.72, 8.53, 9.16, and 9.42 metres per second, the coefficient is 0.8, 0.9, 0.9, 0.9, and 0.88 respectively. With water flow the author remarks that the coefficient is about 0.85. The Krell-Prandtl pneumometer is also described.

Peroxidized Kerosene as Motor Fuel. G. B. SELDEN. (*Petroleum*, ix, 1304.)—Kerosene and other heavy petroleum oils can be utilized as fuel for internal-combustion engines if small quantities of peroxides or other highly-oxygenated substances, such as picric acid or nitronaphthalenes, etc., are either dissolved in them or sprayed into the air inlet of the carburetter. Thus petroleum with 3 per cent. of hydrogen peroxide is stated to be perfectly stable, to differ from the original oil but little in either color, specific gravity, or flash-point, and to burn perfectly clean and without residue in the cylinder or odor in the exhaust. The power of the engine is, moreover, increased. Although aqueous peroxide may be used as a spray, it is preferable to shake the aqueous peroxide with the oil, and allow to separate. The hydrocarbon layer will then contain most of the hydrogen peroxide, and is decanted off. Many nitrated substances have been also employed in amounts varying from 0.5 to 5 per cent. in solution in the oil with similar results. It is claimed, for example, that an addition of 2 per cent. of naphthalene picrate increased the power of the engine by more than 100 per cent. Similar nitrated compounds of naphthalene, phenanthrene, pyrene, and picene have also been used.

Applications of the Coolidge Röntgen-ray Tube. W. P. DAVEY. (*Gen. Electr. Rev.*, xvii, 792.)—The main advantages in the use of the Coolidge tube are: (1) The independence of the quantity and the penetrating ability of the rays produced, (2) the ease and rapidity with which the quantity and penetration of the rays may be regulated, and (3) the fact that when the tube is once adjusted to the requirements of the operator it needs no further attention. To bring the tube to any desired adjustment, the operator pulls a handle which regulates the current through the tube, thus determining definitely the quantity of Röntgen rays produced. He then adjusts the voltage across the tube until the penetration is of the desired degree. The radiographs reproduced show what a wide range of work can be done with a single Coolidge tube, and they suggest that this tube is destined to become a precision-instrument of value to the botanist, biologist, and mineralogist, as well as to the physicist and the physician.

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